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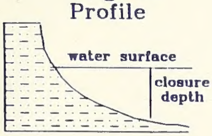

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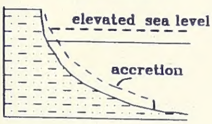

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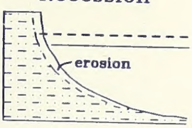

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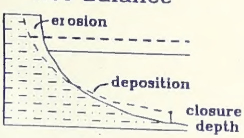

ANNOTATED BIBLIOGRAPHY OF RELATIVE SEA LEVEL CHANGE

by

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PREFACE

The references in this bibliography were assembled during a literature search made to provide background material on pertinent engineering implications on global, regional, and local sea-level changes. The work was completed as a part of the Barrier Island Sedimentation Studies Work Unit 31665 of the Coastal Program. Dr. C. Linwood Vincent was the Coastal Program Manager. The Headquarters, US Army Corps of Engineers, Technical Monitors were Messrs. John H. Lockhart, Jr.; John G. Housley; James E. Crews; and Robert H. Campbell.

This bibliography was prepared by Ms. Laurel T. Gorman of the Coastal Processes Branch (CPB), Research Division (RD), of the Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station (WES). The work was conducted under the general supervision of Dr. Steve A. Hughes, Chief, CPB, RD; Ms. Joan Pope, Chief, Coastal Structures and Evaluation Branch, Engineering Development Division (EDD); Mr. H. Lee Butler, Chief, RD; Mr. Thomas W. Richardson, Chief, EDD, Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC; and Dr. James R. Houston, Chief, CERC. Preparation of the manuscript by Mses. Michelle K. Kindhart and Jackie J. Johnston are gratefully acknowledged.

Director of WES during the publication of this report was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

CONTENTS

INTRODUCTION

1. The purpose of this bibliography is to summarize articles that pertain to the engineering implications of sea-level change for the Corps of Engineer Districts that manage bodies of water under the influence of sea-level changes. Articles cited in this report include references to global, regional, and local sea-level changes with emphasis on quantitative data analysis. In addition, other pertinent topics such as historic (100-year scale) sea-level trends based on regional and local tide gage measurements, physical impacts and coastal geomorphic response to sea-level change for a particular locale, and climatic models of global warming rates are cited.

2. The Corps' interest in sea-level stems from its design and maintenance responsibility for coastal projects. Changes in sea level will not only affect the design life of future projects, but also the operational and maintenance procedures that include hurricane protection, beach-erosion control, and navigational projects. Development of information on long-term water-level fluctuations is an important consideration for navigation in US waterways as well as the effect on daily exchange of water between inland waterways and the open coast. Quantitative assessment of water-level fluctuations will provide better engineering solutions to increased future sea-level rise.

3. References are listed alphabetically by senior author surname. When possible, author abstracts or summaries were reproduced, and when an article or publication provided no abstract or summary, a brief annotation was written. A cross-referenced keyword index and a subject index are provided at the end of this report. The subject index includes the major influences on sea-level that are discussed in the following section of this report. These include climatic effects, global effects, structural/subsidence, national effects that include North American shores, local effects within the east, west and gulf US coasts, lake levels, engineering implications or quantitative analysis, and future planning.

Background

4. This section includes a brief summary of coastal and geological processes that affect sea-level trends and the resulting effects on marine coasts of the United States. References cited in the following text can be found in the annotated bibliography section. In the literature, sea-level variations are usually discussed in reference to one or more time scales, decades, centuries, millennia, or over longer geological time scales. Determination of short-term sea-level trends are based on tide stations that measure relative sea-level changes. These instruments are primarily located at the junction of river systems and ocean waters to determine local fluctuations in water or land levels. To accurately measure the sea elevation, tide gages are referenced to a defined datum (1929 National Geodetic Vertical Datum or local mean sea surface) over a specific time period. Other types of measurements such as oceanographic leveling and, more recently, satellite altimetry are also employed to determine sea-level trends.

Climatic Effects

5. Global warming due to increases in CO_2 is one of the most controversial factors affecting sea-level change. Measuring and predicting the amount of CO_2 gases that has been added to the atmosphere and its effects on sea level is a complex problem due to measurement uncertainties and a general lack of scientific knowledge needed to forecast climatic trends. A general rule of thumb on global warming rates is that if the level of atmospheric CO_2 doubles, the Earth's global temperature increase is projected to be between 3° and 9° C (Hoffman 1983) resulting in a rise of sea level between 70 and 330 cm. In comparison, the rise of sea level was about 15 cm over the last century. Several researchers (Barnett 1983, Revelle 1982, and Gornitz et al. 1982) agree that steric or thermal expansion of the upper layers of ocean waters is not the major contributing factor in sea-level rise. Out of a total projected rate of 70 cm per century for sea-level rise, 30 cm is attributed to warming and expansion of the upper ocean waters while the remaining 40 cm is attributed to glacial melting (National Research Council 1983).

6. Variations in the Southern Oscillation and El Niño are also important climatic factors that contribute to cyclic sea-level variation. Southern

Oscillation is defined as a 2- to 3-year cycle in which there is an alteration of regional pressure anomalies about two nodes, a low-pressure system located over the Indian Ocean and a high-pressure system that is over the southeast Pacific Ocean. Fairbridge and Krebs (1962) concluded that for every 1 mb of pressure increase there is a fall of sea level by 10 mm. Observed El Niño phenomenon in the tropical Pacific Ocean have been explained as a response to changes in the surface wind stress As prevailing winds shift, westerly anomalies accelerate equatorial counter currents and depress the thermocline in the east, reduce equatorial upwelling, and enhance the eastward transport of warm surface waters from the western Pacific (Cane and Zebiak 1985). The connection between El Niño and anomalous ocean behavior in other parts of the world is documented but unexplained. High winds and long fetch can produce long and high waves that add to these extreme sea levels. During the winter of 1982-1983, the California coast was subjected to high tides, frequent storms, and high sea levels associated with El Niño, causing severe storm damage in excess of $100 million (Flick and Cayan 1984).

Global Effects

7. Eustatic changes, or worldwide sea-level fluctuations, have been attributed to: (a) glacio-eustasy, or ocean level changes caused by the melting or formation of glaciers; (b) geodetic changes in ocean basins affected by the Earth's gravity, structure, density, rotation, and astronomical gravity; and (c) tectonic-eustasy that includes the vertical and horizontal movements of the oceanic basins. Background information on the concept of eustasy can be found in Fairbridge (1961), Morner (1973, 1976, 1978, 1981, 1986), and Lisitzin (1974). The global rate of sea-level change varies due to the methodologies used by scientists to measure still-water levels. General consensus, however, is that average global sea-level rates of rise are between 1.0 and 1.2 millimeters/year (Gornitz et al. 1987, Barnett 1983. These rates are dependent on the accuracy of tide-gage measurements, correction for long-term movements, signal in the record, and geographic bias. The estimate of eustatic mean sea-level rise remains biased toward the Northern Hemisphere because of the relatively high number of tide gages.

Structural/Subsidence

8. Tectonic activity is an important consideration in the assessment of sea-level change for areas undergoing crustal movement. Based on long- or short-term time scale, vertical movement of land is due to changes in the pattern of surface loads, either through changes in sea level or from movement of the land. Crustal movement occurs over both long- and short-term time spans. Long-term processes, such as seafloor spreading, displace ocean basin volume resulting in a sea-level rise. Conversely, episodic events such as earthquake and volcanic activity displace land over a short time period often decreasing relative sea-level change. Ridge development and continental margin subsidence also contribute to low-frequency eustatic sea-level fluctuations, whereas glaciation contributes to the higher frequency portion of the sea-level curve (Guidish et al. 1984).

9. Sea-level changes that result from tectonic activity or subsidence are highly variable according to geographic location. Classical case studies indicating distinct trends are described for the following coastlines:

- a. South-central coast of California has experienced high uplift rates of 1 to 6 millimeters/year along the marine terraces.
- b. Hicks, Debaugh, and Hickman (1965) reported uplift rates between 0.37 and 3.96 centimeters/year in southeast Alaska, which experiences frequent earthquake activity and glacial rebound. These measurements are based on continuous sea-level data collected for the period 1909-1962.
- c. Tide-gage readings along the mid-Atlantic states have high rates of sea-level rise as compared with the southern east coast, primarily due to subsidence along the crest of the peripheral forebulge.
- d. The coastline of Japan has experienced anomalously high rates (20 millimeters/year) of relative sea-level rise. Aubrey and Emery (1986) applied regression and eigenanalysis to the local tide gage records for the past 50 years. The resultant sea-level pattern reflects the subduction activity along the Pacific and Philippine plate.

National Effects (North America)

10. In general, most of the North American coastline is experiencing a rise in relative sea level. Excellent sources of US tide gage measurements are two reports published through National Oceanic and Atmospheric

Administration (NOAA), National Ocean Service (NOS). These publications describe the sea-level trends, standard error of sea-level rates, and annual variabilities for the entire US coastline (Hicks, Debaugh, and Hickman 1983; and Lyles, Hickman, and Debaugh 1988). Sea-level trends based on observations of NOS tide stations are listed in Table 1 (Hicks, Debaugh, and Hickman 1983).

11. National concerns and impacts of sea-level rise are summarized in Titus, Henderson, and Teal (1984), and Barth and Titus (1984). By understanding the cause and effect of sea-level rise and implementing strong planning policies, the private and public sectors can avert costly storm damages. Two case studies, as presented in Barth and Titus (1984), evaluate the cumulative economic impact for the Charleston, NC, and Galveston, TX, area. Economic losses for the Charleston area is projected from $280 million in the low scenario (1980-2075) to $2.5 billion for the high scenario (1980-2075). For the Galveston area, the losses would range from $415 million for the low scenario (1980-2025) to $1.8 billion in the high scenario (1980-2075). The economic impacts such as these case studies might be greatly reduced if coastal planners and engineers take the necessary action and precautions.

East US Coast

12. Rates of sea-level rise in the northeast United States range from 1.8 to 4.2 millimeters/year (Hicks, Debaugh, and Hickman 1983). The higher rates reflect regional downwarping of the land due to glacial loading, high frequency of storm activity, and wind setup associated with the bent coastline near New York Harbor. An area that has undergone rapid subsidence as a result of glacial rebound is the Continental Shelf south of New England. For the southeast Atlantic coast, the overall mean sea-level value of 1.9 millimeter/year was considerably less than the values for the northeast coastline due to the tectonic stability of the region.

West US Coast

13. As previously mentioned, the Pacific coast is an active area of crustal movement where the land is uplifted relative to sea level. Records of annual mean sea level along the California coastline show alternate recessional and tectonically uplifted coastlines. For example, Los Angeles is

Table 1

Sea Level Trends from US Tide Gages, 1940-1980, (Hicks et al. 1983)

Location	Trend mm/yr	Standard Error of Trend ±mm/yr	Standard error of Variability ±mm
Eastport, ME	3.2	0.4	28.6
Portland, ME	2.3	0.4	29.7
Seavey Is., ME	1.3	0.3	22.6
Boston, MA	0.9	0.3	23.5
Woods Hole, MA	2.3	0.3	22.0
Newport, RI	2.0	0.3	22.1
Providence, RI	1.8	0.4	26.1
New London, CT	2.2	0.3	23.7
Willets Point, NY	1.6	0.6	44.5
New York, NY	2.5	0.3	25.3
Sandy Hook, NJ	4.0	0.4	29.3
Atlantic City, NJ	3.9	0.4	32.3
Philadelphia, PA	2.3	0.5	41.3
Lewes,DE	2.0	0.8	39.1
Baltimore, MD	2.5	0.4	28.0
Annapolis, MD	3.0	0.4	26.9
Solomons Is., MD	3.2	0.4	28.7
Washington, DC	2.8	0.5	37.1
Hampton Roads, VA	3.6	0.4	32.1
Portsmouth, VA	3.6	0.4	30.7
Charleston, SC	2.4	0.5	36.1
Fort Pulaski, GA	2.5	0.4	33.8
Fernandina, FL	1.6	0.5	34.6
Mayport, FL	1.5	0.5	34.7
Miami Beach, FL	1.9	0.3	24.0
Key West, FL	1.6	0.4	27.2
Cedar Key, FL	1.2	0.4	31.2
Pensacola, FL	1.6	0.5	37.1
Galveston, TX	6.2	0.7	48.1
San Diego, CA	1.6	0.4	27.5
La Jolla, CA	1.5	0.4	28.4
Los Angeles, CA	-0.1	0.4	26.3
San Francisco, CA	1.5	0.4	33.2
Alameda, CA	0.1	0.5	34.6
Cresent City, CA	-1.6	0.4	28.7
Astoria, OR	-1.3	0.5	38.8
Neah Bay, WA	-1.8	0.4	29.0
Seattle, WA	2.1	0.4	27.2
Friday Harbor, WA	0.5	0.4	28.4
Ketchikan, AK	-0.4	0.5	38.6
Sitka, AK	-2.4	0.4	28.9
Juneau, AK	-12.8	0.5	38.3
Yakutat, AK	-4.6	0.4	33.6
Honolulu, HI	0.7	0.4	30.7

rising relative to San Diego, and farther north, San Francisco is rising at an even greater rate compared with Los Angeles. The sea-level trend of -0.4 millimeter/year for the northwest Pacific coast is the result of an emergent shoreline, and sea-level rates for the southwest coast for the same period are 1.0 millimeter/year, which reflects a recessional coastline (Lyles, Hickman, and Debaugh 1988).

Gulf US Coast

14. The gulf coast is experiencing a local, relative rise in sea-level due to subsidence combined with eustatic components. Several studies of the Louisiana coast indicate rates of subsidence of about 10 millimeters/year (Nummedal 1983, and Ramsey and Moslow 1987). The sparsity of tide gages along the Gulf of Mexico, however, has made it difficult to obtain accurate rates of sea-level rise. Another problem with tide-gage information from this area is that many of the gages are not located on stable substrate, which makes it difficult to filter and correct the records. A complex set of interactive factors that contribute to subsidence in the gulf region include: an active sedimentary, deltaic basin; movement along growth faults; removal of ground water, oil, and gas; saltwater intrusion, and dredging and channelization of fluvial systems. Table 2 lists the rate of subsidence reported in the literature for the gulf region.

Table 2

Rates of Subsidence Reported in the Gulf Region

Rate	Location	Reference
3 mm/year	Galveston, Texas	Leatherman 1983
9 mm/year	Louisiana	Nummedal 1983
100 mm/year	Grand Isle Louisiana	Ramsey 1986
12 mm/year	Southwestern Louisiana	Delaune et al. 1983
1.2 mm/year	Southwestern Florida	Scholl 1964

Lake Levels

15. The US Corps of Engineers has supported numerous studies on lake levels in the Great Lakes region (Hands 1976a, 1981, 1984). These reports document the effects of rising lake levels on shore position by monitoring beach profiles. Analysis of the data set indicates fluctuations in lake levels as much as 2 m over a 10-year interval. These changes have resulted in significant erosion of sandy beaches and cliffs bordering the Great Lakes. A recent publication by Bowles and James (1985) discusses the rising level of the Great Salt Lake and the impact on Utah's economy. The recent rise in lake surface has been ascribed to high precipitation, record river flows, and low evaporation in lake water level. On a long-term geological basis, cyclic fluctuations have been recorded as varves or rings that indicate climate variations and historic climatic conditions (Dean et al. 1984). Lake varves or laminae develop as sediments are deposited in still water within a year's time.

Engineering Implications

16. Shoreline response to sea-level rise has been studied in detail by coastal engineers during the past 25 years. Per Bruun (1962) stated that under rising water conditions the beach and upper shoreface profile would erode at the expense of the lower part of the shoreface profile where an equal volume of sediment would be deposited. Many case studies for specific coastal areas have been conducted using Bruun's Rule:

a. Schwartz (1965) verified Bruun's theory using laboratory and field tests.

b. Dubois (1976) applied Bruun's Rule to the nearshore zone at Larry Andrae State Park, Wisconsin.

c. Rosen (1978) verified the relationship of the equilibrium profile along 336-km shoreline on the Virginia Chesapeake Bay.

d. Hands (1976a, 1981, 1984) applied Bruun's Rule to field data collected along Lake Michigan shore over a 9-year period.

e. Everts' (1987) method added a grain-size sediment component to Bruun's Rule for a specific coastal reach based on a minimal 20-year time period.

Another useful source of general guidance in understanding an anticipated rise in sea level is a report commissioned by the National Research Council (1987).

The focus of this report presented various engineering strategies for specific facilities and coastal structures. The committee panel recommended the most appropriate strategy was not to adopt one particular sea-level rise scenario with the realization that development should also include the high probability of future increased rates of sea-level rise.

Future Planning

17. Few articles or reports have addressed the future rates of sea-level rise, since there is no consensus among scientists concerning the complex nature of the interactive factors associated with sea level. The Environmental Protection Agency published a series of reports to address future planning that estimate the rates of global warming, snow and ice contribution, and future sea-level scenarios. If an accelerated rise of sea level occurs as predicted, coastal communities will be faced with deciding the benefits of protection versus the benefits of retreating from the coastline. Long-term costs, remedial costs, and risk of human life and property will have to be evaluated in maintaining coastal structures and facilities. In summary, the focus of research efforts in understanding sea-level change should be on estimates of sea-level rise, improving future scenarios, and developing climatic and glacial process models.

001 **ALLISON, H.** 1980. "Enigma of the Bruun's Formula in Shore Erosion," Proceedings of the Per Bruun Symposium, Newport, Rhode Island, International Geographical Union Commission on the Coastal Environment, Bureau for Facility Research, Western Washington University, Bellingham, Washington, pp 67-78.

Allison evaluated the accuracy of Bruun's formula and considered the effect of shoreward and seaward slopes of the profiles. This paper critically analyzes the application of Bruun's theory used by Schwartz (1965, 1967); Dubois (1975, 1976, and 1977), and Rosen (1978). (Gorman).

002 **ANEJA, V. P., and OVERTON, J. H.** 1989. "Emission Rate of Dimethyl Sulfide at the Atmospheric - Oceanic Interface and Its Role in Global Climate Change," Magoon, O.T., Converse, H., Miner, D., Tobin, L.T. and Clark, D., eds., Proceedings of Coastal Zone '89, American Society of Civil Engineers, Vol 2, pp 1311.

Dimethyl sulfide appears to be present everywhere in the surface ocean, is readily transferred into the marine atmosphere, and may account for about 30% of the natural component of the overall sulfur budget. To investigate the apparent discrepancy between measured DMS fluxes and theoretical predictions, the authors have examined the transport of DMS across the marine-atmosphere interface and analyzed its emission dependence on climatic variables. An analysis of vertical flux was performed with the two-film model for the transport of DMS across the marine-atmosphere interface with chemical reactions. Photo-oxidation of DMS and its reaction with H_2O_2 in the aqueous film, and chemical reactions of DMS with nitrate and hydroxyl radicals in the gas film indicate negligible effect on the DMS flux to the marine atmosphere. However, the flux of DMS into the atmosphere is most sensitive to the liquid film thickness and not so to changes in temperature and gas film thickness. Model calculations showed that if the liquid film thickness increases from 35, 25 μg (turbulent sea conditions) to 200 μm (calm sea conditions), the flux of DMS reduces from 290 to 55 μg (s)/m^2/day. Estimates are made of DMS gaseous oxidation products as a possible source of cloud condensation nuclei to ascertain increased aerosol albedo over the ocean, which may then lead to global climate change. (Modified Abstract).

003 **AUBREY, D. G. and EMERY, K. O.** 1986. "Relative Sea-Levels of Japan from Tide-Gage Records," Geological Society of American Bulletin, pp 194-205.

We attempted to separate tectonic, oceanographic, and eustatic components of change in relative sea-levels derived from the many tide-gage records of Japan acquired over the past fifty years. Both regression and eigenanalysis showed systematic spatial differences in relative sea-level rise that reach about 20 mm/year, far too much to be solely eustatic in origin. The low-frequency patterns are closely related to those expected from

subduction of the Pacific and Philippine plates beneath Japan. Higher frequencies, 2, 6, and 12 year ones, probably are caused by oceanographic factors such as shifts in the position of the Kuroshio. The contours of relative change in sea-levels provide convincing evidence that no one or several Japanese tide gages can be selected to authentically denote present or past eustatic sea-levels. We introduce a modified eigenanalysis to permit use of station data of unequal lengths. (Authors).

004 **AUBREY, D. G ., and EMERY, K. O.** 1983. "Eigenanalysis of Recent United States Sea-Levels," Continental Shelf Research, Vol 2, No. 1, pp 21-33.

Spatial and temporal patterns of recent sea-level rise along the United States coastline have been examined to ascertain rates of rise, and possible causes for high-frequency fluctuations in sea-level. Eigenanalysis identified several distinct coastal compartments within each of which sea-level behavior is consistent. The United States east coast has three of these compartments: one north of Cape Cod, where sea-level rise increases with distance to the north; one between Cape Cod and Cape Hatteras where sea-level rise increases to the south; and the third from Cape Hatteras south to Pensacola, where sea-level rise decreases to the south. The western gulf coast represents another compartment (poorly sampled in this study), where subsidence is partly due to compaction. The final compartment is along the United States west coast, where poor spatial sampling produces a highly spatially variable sea-level record that has some temporal uniformity. Spectral analysis shows a dominant time scale of 6 years for sea-level variability, with different coastal compartments responding relatively in or out of phase. No evidence for increased rates of sea-level rise over the past 10 years was found. This objective statistical technique is a valuable tool for identifying spatial and temporal sea-level trends in the United States. It may later prove useful for identifying elusive world-wide trends of sea-level, related to glacial melting, glacial rebound, tectonism, and volcanic activity. (Authors).

005 **AUBREY, D. G., and EMERY, K. O.** 1986. "Australia--An Unstable Platform for Tide-Gage Measurements of Changing Sea-Levels," Journal of Geology, Vol 94, pp 699-712.

Twenty-five tide-gage records non-uniformly distributed along the coast of Australia were used to evaluate the stability of Australia as a platform from which to measure changes in sea-levels. The spatial and temporal variabilities of relative sea-levels were defined using a multivariate analytical tool (eigenanalysis) on 13 of these stations. Low-frequency (period 20 years and greater) relative sea-levels are believed to reflect the combined effects of subsistence due to sediment and water loading, subsidence due to thermal cooling of oceanic crust, and emergence along a convergent plate boundary. Global eustatic sea-level rise cannot be identified unambiguously from these data, but clearly it is not responsible for the observed patterns of relative sea-level. The straight average rate-of-rise of relative sea-level around Australia is 1.3 mm/year. (submergence), with general submergence in the south (at an average rate of 1.8 mm/year.) and

emergence in the north (0.5 mm/year, the latter an average of two stations). Australian tide-gage data cannot define unambiguously past eustatic sea-level history because of this considerable spatial non-homogeneity in relative sea-level rise, but they may be useful for monitoring possible future increases in rate of global sea-level rise. Higher-frequency fluctuations in relative sea-levels show relative peaks at 20, 12, and 6 years, with significant energy at higher frequencies as well. Higher frequency fluctuations correlate with patterns of El Niño/Southern Oscillation. During El Niño events, yearly-averaged sea-levels of Australia fall, although not all local minima in relative sea-levels correspond with El Niños. The resultant drop in relative sea-levels represents a balance between lower sea-levels due to raised atmospheric pressure with coincident lowered water temperatures, and higher steric sea-levels due to increased precipitation and runoff (for those stations located in estuaries). (Authors).

006 **BAOCAN, W.** 1984. "Sea-Level Change and Beach Process - A Case Study in South Zhejiang Beach," Marine Geophysical Researches, Vol 7, pp 307-317.

This paper describes Holocene sea-level changes off the coast of China. The evidence concerning low sea-level during the last glacial phase, Holocene marine transgression which was discovered from sea bottom in East China Sea and China's bordering seas, and their adjacent coastal areas, where, by drilling, relic sediment, peat deposit, and mollusc shell fossils have been obtained, and their dates are deduced through measurement of radiocarbon (C^{14}), identified that low sea-level about 15,000 years ago stood in the depth of 150 m below the present level in East China Sea, and that the subsequent transgression carried the sea up to the present sea-level 6,000 years ago, when the present China's coast and other continent's coasts were outlined.

Due to a number of factors, the sea-level oscillates seasonally in the border sea of China. Generally, the annual range of the seasonal changes in sea-level is about 35 m off the south Zhejiang coast, where the highest value of 20 cm occurs in September, and the lowest of -15 cm occurs in March. The reason may be mainly due to the seasonal variations of climate and river run-off, as well as the Taiwan Warm Current. Similar seasonal oscillations in sea-level also occur in Bohai Gulf, Yellow Sea, East China Sea and the South China Sea.

The beach response of south Zhejiang is strongly affected by the seasonal oscillations in sea-level. The width of beach is 4 to 6 km, the slope is approximately in 1:1000. If the sea-level rises or falls 1 cm, the beach submergence or emergence is led to be about 10 m in width. As a result, the relative equilibrium of beach will be changed by the seasonal oscillations in sea-level. (Modified Abstract).

007 **BARNETT, T. P.** 1983. "Global Sea-Level: Estimating and Explaining Apparent Changes," Proceedings of Coastal Zone '83, Vol III, pp 2777-2783.

A new analysis of "global" sea-level has been made that largely avoids space/time bias of previous works. A coherent pattern of increasing relative sea-level (RSL) was found to exist on average at all stations analyzed between

1903-1969. Subject to considerable assumption, the rate of RSL increase associated with this pattern was 15 cm/century. A similar analysis of the period 1930-1975 again showed RSL increasing on average everywhere but in the western half of the North Pacific Ocean. Decrease of RSL in this areas was substantiated by hydrographic data. Thus, in recent years the concept of a "global" sea-level rise is not supported. The temporal behavior of the <u>near</u> global signals from both time periods was well approximated by a simple linear trend. There was no evidence of a more rapid rise in RSL in recent years.

Potential causes of the above RSL change were investigated. Changes in the position of the earth's axis of rotation support the idea that the RSL change was due to approximately equal melting of Greenland/Antarctica. Changes in the length of day only marginally support this idea. However, other attractive geophysical explanations for variations in both these astronomical parameters exist. Observed change in sea surface temperature (SST), if representative of reasonable changes in vertical thermal structure, could give the observed RSL change. However, thermal expansion of the oceans would not significantly affect the rotational parameters although changes in these parameters could be due to non-RSL related processes. Changes in ocean circulation and/or subsidence along all the coastal margins simultaneously seem unlikely causes of the observed change in RSL. In the study findings, it is not concluded possible at this time to explain reliably the apparent increase in RSL. (Modified Abstract).

008 BARNETT, T. P. 1984. "The Estimation of 'Global' Sea-Level Change: A Problem of Uniqueness," <u>Journal of Geophysical Research</u>, Vol 89, No.C5, pp 7980-7988.

An objective method of estimating regional averages of coherent sea-level (SL) change is developed. The technique is applied to a large set of SL data representative of most of the world's continental margins. The results show highly coherent SL changes over many of the regions studied. The method is then applied to the regional averages themselves to develop an overall estimate of the coherent pattern of SL variations existing in the historical SL data set. The pattern is characterized by a coherent rise of SL in all regions except Alaska, Scandinavia (both areas of notorious crustal uplift), and Southeast Asia. The period since that time has seen an increase in SL that is optimally fit by linear trend of 23 cm/century. The study results suggest that it is not possible to uniquely determine either a global rate of change of SL or even the average rate of change associated with the existing (inadequate) data set. Indeed, different analysis methods, by themselves, can cause 50 percent variations in the estimates of SL trend in the existing data set. A signal/noise analysis suggests it should be easy to detect small, future changes in the SL trends estimated for the period 1930-1980. However, detection of theoretically predicted low-frequency signals (e.g. caused by CO_2 warming) will be difficult in view of the huge, low-frequency, natural variability associated with glacial/tectonic processes. (Author).

009 **BARRY, R.** 1984. Possible CO_2 - Induced Warming Effects on the Cryosphere: Climatic Changes on a Yearly to Millennial Basis, Morner and Kurlen, eds., D. Reidel Publishing Company, pp 571-604.

Over the last few years, considerable attention has been given to the possible climatic effects of increasing atmospheric carbon dioxide concentrations. The present figure of 340 p.p.m. by volume is 15 to 20 percent above pre-industrial levels and a concentration of double the assumed 1860 value of 295 ppm has been projected by the second half of the next century due to continued burning of fossil fuels (Laurmann and Rotty, 1983). Climate modelling simulations suggest that such a doubling will cause a global mean surface air temperature rise of about 3.0 + 1.5 K (National Research Council, 1982), with at least a two- to three-fold amplification in high latitudes. Hansen et al. (1981) estimate that the post-1890s CO_2 increase should already have caused a 0.5°C warming, but allowing for oceanic heat capacity and mixing effects this would be reduced to 0.2°C. Further modifications of climatic regimes will occur through changes in precipitation and circulation characteristics, although these are less well known.

Preliminary assessments of the possible impacts of these projected climatic perturbations on global snow and ice cover have already been reported (Barry 1978; Hollin and Barry, 1979) This study updates those reports and attempts to develop a composite picture from modelling results, analytical projections, and analogues based on other "warm" climatic intervals. Other analyses have focused primarily on the possible disappearance of the Arctic pack ice (Parkinson and Kellogg, 1979; Flohn, 1982) and on the possible disintegration of the West Antarctic ice sheet and its consequences for global sea-level (Mercer, 1978; Thomas et al. 1979; Young, 1981; MacDonald, 1982, Bentley, 1983; Schneider and Chen, 1980). Other potential effects have received much less attention. (Introduction).

010 **BARTH, M. C. and TITUS, J. G. (Editors).** 1984. Greenhouse Effect and Sea-Level Rise, Va. Nostrand Reinhold Company Inc., New York.

This book estimates the magnitude of future sea-level rise, its effects, and the value of policies that prepare for these consequences. The authors conclude that the evidence of at least a small rise is so compelling that some policy changes are warranted even today. Moreover, the consequences of a larger rise that may occur and the resources that could be saved by anticipatory actions are so great that the private and public sectors must start to prepare for this possibility, even though uncertainties remain. Because better predictions of future sea-level rise could enable coastal communities to save billions of dollars, the authors also conclude that a substantial acceleration of this research would be economically justified and is urgently needed.

This book is based on papers presented in the spring of 1983 at the conference on sea-level rise sponsored by the U.S. Environmental Protection Agency. Authoritative studies investigate:

- climate sensitivity to increasing greenhouse gases
- future sea-level rise scenarios

- effects of sea-level rise on erosion, inundation, storm surge and saltwater intrusion
- methods for controlling erosion, inundation, and saltwater intrusion
- economic effects of sea-level rise and the value of planning for it
- implications of sea-level rise for hazardous waste sites
- planning for sea-level rise before and after a coastal disaster

The case studies of Charleston, South Carolina, and Galveston, Texas, highlight the hazards and decisions facing shore communities as well as factors influencing individual decisions, such as where and how to rebuild after a storm. (From book jacket).

011 BAUM, G. R., and VAIL, P. R. 1988. "Sequence Stratigraphic Concepts Applied to Paleogene Outcrops, Gulf and Atlantic Basins," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 309-328.

Type 1 and type 2 sequence boundaries can be used for regional correlation in seismic, wireline log, and outcrop data. Marine condensed sections (zones of markedly reduced sedimentation) divide these sequences and are recognized seismically as downlap surfaces. Sequence boundaries can be dated at their basinward correlative conformities. Depositional sequences are not synthems or allostratigraphic units. Synthems or allostratigraphic units are extended only as far as both of the bounding unconformities or discontinuities are identifiable. Sequences are bounded by unconformities and their correlative conformities and so are identifiable beyond the extent of their bounding discontinuities. Because most of the exposed Paleogene units in the Gulf and Atlantic basins were deposited landward of their respective shelf slope breaks, evidence of deposition of deep-sea fans common to type 1 unconformities. Typically, the incised valleys are onlap-filled with reservoir-prone fluvial to estuarine sediments. In additional, sequence boundaries are characterized by abrupt downward shifts in facies with relatively shallower water facies resting sharply on relatively deeper water facies. In carbonates, subaerial unconformities are typically characterized by mesokarst, phosphate pebble conglomerates, and sediment fill of early moldic porosity.

Condensed sections are characterized by anomalous concentrations of mammillated-to-lobate glauconite, planktonic organisms, phosphate, and exotic minerals, and by glauconitized/phosphatized surfaces commonly associated with hardgrounds or burrowed omission surfaces. Hardgrounds are characterized by intercrystalline sediment fill after subaqueous, acicular, bladed, and/or pelloidal marine cements, and by abrupt shifts to more negative values of calcite above the hardgrounds associated with condensed sections.

Application of these concepts to outcrop studies reveals that many stage boundaries are typically not placed at sequence boundaries. Rather, they are defined either by micropaleontologic hiatuses and/or planktonic zonal

boundaries associated with condensed sections, or by transgressive (flooding) surfaces overlying incised-valley-fill sediments. Also, the currently recognized European and Gulf Coast stages do not adequately reflect the higher frequency coastal-onlap cycles recognized in outcrop. Because most micropaleontologic zones appear to span sequence boundaries, the current micropaleontologic zonations cannot, at present, precisely define a sequence boundary in time. They can approximate sequence position, however. By integrating physical stratigraphy, seismic stratigraphy, and paleontology, these higher frequency eustatic events can be resolved and fixed in a relative time framework. (Authors).

012 **BEARD, J. H., SANGREE, J. B., and SMITH, L. A.** 1982. "Quaternary Chronology, Paleoclimate, Depositional Sequences and Eustatic Cycles," American Association of Petroleum Geologists, Bulletin 66, No. 2, pp 158-169.

Pleistocene alternations of ocean volumes, expressed as relative changes in sea-level, are symptomatic of the accumulation and melting of continental ice sheets and resulted in lowstands of sea-level during glacial periods and highstands during interglacial periods. A lowstand-highstand constitutes a eustatic cycle. Eight cycles that occurred during the last 2.5 to 3.0 m.y. are recognized in the Gulf Coast region. These cycles are identified by multiple criteria, including paleontologic, sedimentologic, and seismic evidence. Eustatic cycle concepts can be used in seismic stratigraphy to identify seismic (depositional) sequences. Such seismic-sequence analyses are based on identification of discrete stratigraphic units within relatively conformable intervals of strata by using reflection patterns on the seismogram. For example, glacial periods may exhibit chaotic bedding surfaces on the seismogram, whereas interglacial periods may display parallel bedding surfaces. Seismic sequence analyses provide a sound basis for applying the global system of geochronology to seismic data for the improvement of stratigraphic and structural interpretations. Moreover, seismic sequence analysis in new exploration areas allow for reliable predictions of geologic age ahead of drilling and facilitate preliminary tectonostratigraphic reconstructions. (Authors).

013 **BELKNAP, D. F., and KRAFT, J. C.** 1977. "Holocene Relative Sea-Level Changes and Coastal Stratigraphic Units on the Northwest Flank of the Baltimore Canyon Through Geosyncline," Journal of Sedimentary Petrology, Vol 47, No. 2, pp 610-629.

A new local curve of relative sea-level change for the Delaware coastal area is based on 88 radiocarbon dates. The curve is smooth with relatively narrow potential limits of variation in amplitude. It has a somewhat steeper slope than published eustatic sea-level curves and other local relative sea-level curves. Holocene radiocarbon isochroms in Delaware marsh sections are horizontal. Interpretations strongly support the concept that Holocene sea-level rose slowly and continuously relative to the Delaware coast; the favored hypothesis is that eustatic rise of sea-level was responsible. No seaward tilting is indicated for the Delaware segment of the Atlantic coastal plain or

inner shelf. However, radiocarbon-damed shallow-water samples of comparable age suggest a strong seaward tilt of the outer continental shelf. The outer shelf over the Baltimore Canyon trough geosyncline has subsided approximately 40 m in the last 10,000 years. (Authors).

014 **BELKNAP, D. F., ANDERSEN, B. G., ANDERSON, R. S., ANDERSON, W. A., BORNS, H. W., JR., JACOBSON, G. L., KELLEY, J. T., SHIPP, C. R., SMITH, D. C., STUCKERNATH, R., JR., THOMPSON, W. B., and TYLER, D. A.** 1987. "Late Quaternary Sea-Level Changes in Maine," Nummedal, D., Pilkey, O.H., and Howard, J.D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 71-86.

On the Maine coast, evidence of local relative sea-level 12.5 ka is now exposed 60-80 m above present sea-level. At that time, eustatic sea-level was at least 70 m below present in most parts of the world. The difference is due to isostatic depression of the Maine coast by the weight of glacial ice. During deglaciation, the sea advanced inland in contact with the retreating margin of the marine-based ice sheet. Due to isostatic rebound and the contours of the land, the ice sheet grounded as much as 150 km inland of the present coast, glaciomarine deltas formed, and the transgression reached a stillstand at what is termed the upper marine limit. Due to differential tilting during rebound, this marine limit is now over 132 m in elevation at its farthest inlet extent. As rebound became dominant, sea-level reached to 65 m below present at about 9.5 ka. At that time rebound slowed to about the same rate as that of eustatic sea-level rise. Shorelines were cut and deltas were formed at this lower marine stillstand position. Subsequently, eustatic rise became the predominant mode. Radiocarbon dates on fossil marine mollusks provide timing for this onlap and offlap.

From 7.0 ka to the present, radiocarbon dates on wood and salt marsh peats provide a relatively precise sea-level curve. During the period 4.2-1.5 ka, sea-level rose at 1.22 m/1,000 years. Before that period, it may have risen more than twice as fast. After 1.5 ka, it slowed to half the mid-late Holocene rate. Recent tide-gage records show an acceleration in rate to 2-3 mm/year for the past 40 years. Releveling, tide gages, and other evidence (Anderson and others, 1984) suggest that the coast is being warped downward to the east possible due to non-glacially induced neotectonics. (Authors).

015 **BELKNAP, D. F., and KRAFT, J. C.** 1981. "Preservation Potential of Transgressive Coastal Lithosomes on the U.S. Atlantic Shelf," Marine Geology, Vol 42, pp 429-442.

Migration of coastal lithosomes across the continental shelf is a response to the latest Quaternary rise in sea-level. Variable fractions of the transgressive sequence may be preserved, depending on pre-existing topography, depth of erosion, wave energy, sediment supply, erosion resistance, tidal range, and rate of relative sea-level change. Materials at greater depth in the stratigraphic column are more likely to be preserved. Sediment samples, seismic profiles, and bathymetric observations, indicate

better preservation of shoreline elements on the outer shelf and more reworking on the inner shelf. This is hypothesized to be due primarily to the rate of sea-level rise.

A relative sea-level curve of Delaware, obtained from radiocarbon dates on basal peats, rises smoothly from 25 m below present sea-level 10,000 years B.P. The rate of rise decreases with time. Sea-level rise resulted in rates of coastal retreat of 20 m/year 10,000 years B.P., 5 m/year 5,000 years B.P., and 1.5 m/year at present. The long-term average rate of coastal retreat throughout the Holocene was 10 m/year. In a conceptual model of constant volume of net erosion per unit length of coast, smaller depths of erosion are envisioned during the periods of rapid coastal retreat early in the transgression, allowing a greater preservation potential. During the present slower rate of sea-level rise and coastal retreat, depths of erosion are greater, averaging 10 m off Delaware. In this situation, there is a decreased potential for preservation of the coastal environmental lithosomes in a continuing transgression. Changes in factors such as wave climate, sediment supply, tidal range, and tectonics affect this simple model. (Authors).

016 **BIGFORD, T. E.** 1989. "Sea-Level Change, Fisheries, and Coastal Planning," Magoon, O.T., Converse, H., Miner, D., Tobin, L.T. and Clark, D., eds., Proceedings of Coastal Zone '89, American Society of Civil Engineers, Vol 2, pp 1333.

Several researchers have forecast a slow yet perceptible global warming that could alter sea-levels and coastal industries, particularly our commercial and recreational fisheries. This paper assumes the prevailing opinion that we are experiencing an unusually rapid climatic change and that the next century may witness, a significant shift in our coastal shorelines. It is felt that a transition period for near shore fisheries, and further stress on fishery resources already burdened with numerous ecological insults. This paper reviews how global climate may prompt sea-level changes that could affect fish habitats, valued recreational and commercial species, and related industries. (Modified Abstract).

017 **BIRD, E. C. F., and KOIKE, K.** 1986. "Man's Impact on Sea-Level Changes- A Review," Journal of Coastal Research, Special Issue No. 1, pp 83-88.

The International Geographical Union's Commission on the Coastal Environment identified a range of coastline changes, documented over the past century on a global basis, as the outcome of the project on Coastline Changes carried out from 1972 to 1984. Important among the Commission's findings was the evidence for a modern prevalence of erosion on the world's sandy coastline, sectors of continuing progradation being limited and localized. One of the factors which has been identified as a contributory cause is the possibility that a recent and continuing sea-level rise has contributed to the submergence and erosion of sandy coastlines.

In this report the topic is reviewed under two headings: (1) the essentially local effects of structural works and coastal land reclamation on

sea-levels and (2) the indirect effects resulting from climatic changes taking place in response, at least in part, to increasing pollution and modification of the global atmosphere.

The following are the current views of man's impact on sea-level changes: (1) Man's activities have undoubtedly led to changes in sea-level locally, in response to construction works and subterranean extractive projects; (2) utilization of river waters and construction of coastal dams have clearly influenced the large scale changes, and (3) on the global scale there appear to be some indications of a slight marine transgression which might be due, at least in part, to the effects of accumulation in the Earth's atmosphere of carbon dioxide and other trace gases generated by men's activities. Although some parameters (such as biospheric absorption of increasing atmospheric carbon dioxide) have not yet been adequately assessed, the trend of atmospheric modification by man's activities so far monitored does indicate the possibility that we are about to enter a phase of sea-level rise linked to man's activities. (Authors).

018 **BISCHOFF, J. L., ROSENBAUER, R. J., and SMITH, G. L.** 1985. "Uranium-series Dating of Sediments from Searles Lake: Differences Between Continental and Marine Climate Records," Science, Vol 227, pp 1222-1224.

One of the major unresolved questions in Pleistocene paleoclimatology has been whether continental climatic transitions are consistent with the glacial δ^{18} marine record. Searles Lake in California, now a dry salt pan, is underlain by sediment layers deposited in a succession of lakes whose levels and salinities have fluctuated in response to changes in climate over the last 3×10^6 years. Uranium-series dates on the salt beds range from 35×10^3 to 231×10^3 years. This range of dates allows identification of lake-sediment horizons that are time correlatives of the boundaries of marine isotope stages from the recent 3/4 boundary back to the 8/9 boundary. The 5/6 boundary coincided with a deepening of the lake, but the analogous 1/2 boundary coincided with desiccation. The 3/4, 4/5, 6/7, 7/8, and 8/9 boundaries correspond in age to horizons that record little or no change in sedimentation or climate. These hydrologic results demonstrate that the continental paleo-climate record at this mid-latitude site does not mimic the marine record. (Authors).

019 **BLACKMAN, D. L.** 1985. "New Estimates of Annual Sea-Level Maxima in the Bristol Channel," Estuarine, Coastal and Shelf Science, Vol 20, pp 229-232.

The storms of 13 December 1981 caused observed still water levels in the Britol Channel to exceed previous estimates of the maximum return levels as computed by Graff (1981). These estimates have now been updated for the ports of Swansea, Cardiff, New Port and Avonmouth using more recent data, including the 1981 event, and some historical data not included by Graff. (Introduction).

020 BLAHA, J., and REED, R. 1982. "Fluctuations of Sea-Level in the Western North Pacific and Inferred Flow of the Kuroshio," Journal of Physical Oceanography, Vol 12, No. 7, pp 669-678.

Monthly sea-level elevations at Naze and Aburatsu, sites on either side of the Tokara Strait through which the Kuroshio flows, were analyzed for the period 1963-74. The sea-level elevations were adjusted to uniform atmospheric pressure using a barometric factor of 1 cm mb^{-1}. The adjusted elevations are presented as 1) long-term mean seasonal values and 2) deviations from the long-term means. Differences in the elevations between the two sites were then used as indices of the transport of the Kuroshio.

The seasonal amplitude of the elevation differences across the Kuroshio, Naze minus Aburatsu, is ~13% of the mean surface geopotential anomaly difference of 0.6 dyn m (0/1000 db). The phase of this difference signal indicates maximum northward flow in summer. Zonally integrated wind-stress curl at this latitude in the Pacific interior, however, is most anticyclonic during winter. Instead, the seasonal fluctuations of the Kuroshio are more nearly in phase with the fluctuations in the latitudinal gradients of Ekman pumping in the western North Pacific. The seasonal winds between 7 and 15° N drive a westward interior flow to the western boundary, and winds north of 15° N drive flow away from the western boundary. We speculate that this mechanism effects the seasonal fluctuations of the Kuroshio. The seasonal cycle of Ekman pumping, particularly between 11 and 19° N, is not constant across the Pacific, which helps to reconcile seasonal differences in the fluctuations of the Kuroshio and the North Equatorial Current.

Significant interannual variations are observed in the Kuroshio and at sea-level stations within the North Equatorial Current, e.g. at Guam and Legaspi (Philippines). However, there are fluctuations clearly associated with El Niño at Legaspi, Guam and San Diego which do not appear in the Kuroshio during the 12-year period we examined. (Authors).

021 BLAHA, J. P. 1984. "Fluctuations of Monthly Sea-Level as Related to the Intensity of the Gulf Stream From Key West to Norfolk," Journal of Geophysical Research, Vol 89, No. C5, pp 8033-8042.

Tide gage data from Key West to Norfolk were used to identify a monthly signal in sea-level that is uncorrelated with local shelf-trapped processes. Time series (1955-1975) of local winds, sea-level slope, and river runoff were used in a regression model of sea-level to separate a local response and a residual signal. The monthly means of the residual contribution were investigated for their relationship to the seasonal fluctuations of the Gulf Stream. In the Florida Channel, lower sea-level is found to correspond to increased flow of the Florida Current. During July and August a marked fall in residual sea-level, unrelated to the coastal winds, is found from Key West to Charleston, suggesting that the transport of the Gulf Stream increases both in and north of the Florida Channel during this time. Measured long-term monthly surface currents at Diamond Shoals, Cape Hatteras, which markedly increase in summer to high velocities, tend to substantiate this claim. An additional wintertime low in residual sea-level occurs north of the Florida Channel. The wintertime low does not result from steric heating within the upper 100-150 m of water, nor does it, in contrast to the summertime low,

appear to coincide with increased northward surface flow. Monthly mean Sverdrup transport was computed across the North Atlantic between 15°N and 35°N. When compared at the same latitude, residual sea-level and Sverdrup transport, both interpreted as indices of Gulf Stream transport, generally disagree in phase during summer. However north of the Florida Channel they are consistent during winter, assuming that lower sea-level at this time reflects increased flow in the stream. (Author).

022 BLAHA, J., and STURGES, W. 1987. "Slope of Sea-Level from Miami to Atlantic City," Journal of Physical Oceanography, Vol 17, pp 177-184.

Results of land leveling do not agree with oceanographers' expectations concerning coastal slopes of sea-level. Recent studies have shown that along the west coast of the United States this discrepancy can be explained by the vertical movement of leveling benchmarks. On the east coast, where the movement of benchmarks is not expected, land leveling suggests that sea-level should rise as much as 30 cm from Miami, Florida, to Charleston, South Carolina. However, oceanographers find that sea-level falls, from south to north, approximately 15 cm along the shoreward edge of the Gulf Stream. The discrepancy between these findings could be explained if oceanographic effects that support large alongshore slopes, and that arise primarily on the continental shelf, could be identified. We examine coastal wind stress and runoff as two such forcing mechanisms. To do this, we derive a statistical model of the alongshore change of sea-level between tide gages, based on the alongshore momentum equation. The computed mean sea-level differences are only 1-2 cm between pairs of tide gages, and the signs change from one pair of stations to the next. The conclusion is that the forcing mechanisms that we have studied cannot explain the slopes found by land leveling.

The model is able to predict the seasonal variation of slope between Charleston and Fernandina and between Atlantic City and Norfolk. The observed differences (~8 cm) compare well with the model-computed differences between these sites. Thus, along these sections of coastline, close to shore, we conclude that the seasonal variations of slope seem to be forced largely by coastal winds. On the other hand, only half of the seasonal range observed between Fernandina and Miami and between Norfolk and Charleston could be modeled as effects of wind stress and runoff. The effects of other forcing mechanisms may be more important in these areas. (Authors).

023 BLOOM, A. L. 1959. "Late Pleistocene Changes of Sea-Level in Southwestern Maine," Office of Navel Research, Project No. NR 388-040, pp 143.

The evidence of late Pleistocene marine submergence of the coastal plain of southwestern Maine consists primarily of a sheet of gray, silty clay, containing a cold-water marine fossil fauna. The name "Presumpscot Formation" is proposed for this sediment, from exposures in the Presumpscot River Valley near Portland, Maine. In the eastern one-third of the area, the Presumpscot Formation unconformably overlies glacial drift, and is known from well logs to overlie drift at depths of at least 60 ft below present sealevel; an interval of subaerial exposure of the deglaciated landscape prior to submergence is indicated. This area of postglacial marine submergence coincides with an area of inferred southward flow of glacier ice.

Glacial lineations show that the final movement of glacier ice over the western two-thirds of the area was toward the southeast, from the direction of the White Mountains. This glacial advance entered the sea and deformed previously-deposited beds of the Presumpscot Formation when sealevel was at least 40 ft above its present position relative to the land. It is named the Kennebunk glacial advance from glacially-deformed marine beds exposed near Kennebunk, Maine.

Ice of the Kennebunk advance was impeded in its movement by a rugged upland region northwest of the coastal plain. Local bedrock relief of up to 1000 ft finally separated the thinning ice into detached valley-filling segments, which melted simultaneously over an area at least 25 mi wide from southeast to northwest. During this time of final deglaciation, the marine transgression reached its maximum extent. A line of deltas and delta fans built by meltwater streams marks the inland limit of marine submergence. The strandline of maximum submergence now increases in altitude toward the north at about 2 ft/mi, providing one linear component of postglacial differential upwarping.

Marine submergence may have been in progress 11,800 year B.P., based on one C^{14} age determination on marine shells from Waterville, Maine. Pollen stratigraphy implies that re-emergence was in progress 7,000-8,000 year. B.P. Emergence was accompanied by differential upwarping toward the northwest, presumably the result of postglacial isostatic recovery of the Earth's crust. At some time between 7,000-8,000 year B.P. and 4,200 year B.P. the coast of southwestern Maine was emerged at least 2 ft. and perhaps 8-9 ft greater than present. Progressive submergence has continued from then to the present time.

If eustatic sealevel has been near its present position for the past 5,000 years, as is suggested by accumulating evidence, then either the isostatic movement of the coast of Maine has reversed its direction, or other tectonic movements are causing coastal subsidence. (Author).

024 BLOOM, A. L. 1967. "Pleistocene Shorelines: A New Test of Isostasy," Geological Society of America, Bulletin No. 78, pp 1477-1494.

Recent geophysical studies of glacial isostatic deformation overlook the same fact that was overlooked in earlier studies: The loads of ice that were applied to continents during glacial ages were not loads added to the Earth's crust, but were loads transferred from the oceanic 70 percent to the glaciated 5 percent of the crust by the hydrologic cycle. A realistic model of glacial isostasy must be represented by a balance, in which glaciated areas totaling about 5 percent of the Earth's surface have loads of 140 to 170 bars added or removed on a time scale of 10^4 years, while synchronously the oceanic 70 percent of the Earth's surface has a load of 10 to 12 bars or more removed or added on a similar time scale. The subcrustal mass transfer involved in such a balance is not well represented by harmonic equations, for the water and ice loads are not symmetrically disposed on the Earth's surface.

The suitability of the proposed balance model depends on whether the ocean floor will respond isostatically to a load of as little as 10 bars. Evidence from Lake Mead, Arizona, and Lake Bonneville, Utah, suggest that the continental crust, at least, does deform under a regional load of 10 bars or less.

Pleistocene marine shorelines offer a means of testing the balance model of isostasy. If the ocean floor deforms under water loads, the amount of postglacial submergence of a coast should be in part a function of the regional proximity of deep ocean water. Coasts with nearby ocean water more than 100 m deep had the load of water from the postglacial rise of sea-level added early and close; coasts bordering shallow seas had the load added late and generally far offshore. An averaging technique to show the regional water load on the Atlantic coast of the northeastern United States provides a basis for comparing the submergence histories of several localities with the average water depth offshore. In general, the amount of submergence is proportional to the proximity of deep water.

Oceanic islands should record different Pleistocene shoreline levels than continental coasts. Local, detailed, late Pleistocene histories of a variety of coasts will provide a test of isotasy better than the familiar test of postglacial uplift. (Author).

025 BLOOM, A. L. 1970. "Holocene Submergence in Micronesia as the Standard for Eustatic Sea-Level Changes," Quaternaria, Vol XII, pp 145-154.

The author discusses the effects of Holocene sea-level movements on a "stable coast." Bloom used the small island of Micronesia as case studies and found that slow subsidence averaged close to 3 cm per 1,000 years. (Gorman).

026 BORN, G. H., TAPLEY, B. D., and RIES, J. C. 1986. "Accurate Measurement of Mean Sea-Level Changes," Journal of Geophysical Research, Vol 91, No. C10, Vol 11, pp 775-11, pp 782.

This paper examines a novel yet simple technique for monitoring changes in global mean sea-level over periods of weeks to years with an accuracy of a few centimeters using altimeter data from a well-tracked satellite. The technique is based on the following argument. A satellite's orbit period and, hence, the mean semimajor axis of the orbit, are accurately determined by tracking systems located on the earth's surface. With laser or radiometric tracking systems, the mean semimajor axis can be determined with an accuracy of better than a centimeter. If the satellite carries an accurate altimeter, the difference between the mean semimajor axis and the global mean height measured by the altimeter is mean sea-level. Any temporal change in the measurement of sea-level must be due to drift in the altimeter or to change in the volume of the sea. To demonstrate the application of this technique, the fully corrected altimeter measurements of sea-level obtained by Seasat during a 24-day period when the satellite was in an exactly repeating orbit were separated into eight 3-day segments and averaged over each of these periods. The calculated mean sea-level relative to the Goddard Earth Model-10B geoid varied over a range of ± 7 cm during these eight periods. The variation is due primarily to errors in the vertical component of the satellite's ephemeris, which had a standard deviation of approximately 1.3 m. The results have important consequences. The proposed Topex/Poseidon altimetric satellite mission should have an ephemeris error of around 10 cm, and the satellite's ground track will repeat every 10 days. Thus, we expect that data from this satellite could be

used to monitor variations in mean sea-level with an accuracy of 1 or 2 cm during the 3 to 5 year duration of the mission. Errors in the observations will be due primarily to either drift in the altimeter or orbit error. If an alternate technique is available to monitor the altimeter drift, the measurements can be sued to monitor mean sea-level with an accuracy which may be sufficient to detect global climate change. (Authors).

027 **BOWDEN, A. R. and COLHOUN, E. A.** 1984. "Quaternary Emergent Shorelines of Tasmania," Coastal Geomorphology in Australia (edited by B. G. Thom), pp 313-342.

Tasmania with its northern Bass Strait islands and southern submarine rises forms the continental continuation of southeastern Australia. This insular region has been influenced by Tertiary and Quaternary sea-level changes. Former studies of Tasmanian Quaternary shorelines assumed that stable or quasi-stable tectonic conditions prevailed (Lewis, 1935; Edwards, 1941, Davies, 1959; Jennings, 1959, 1961; Chick, 1971; Kershaw and Sutherland, 1972). However, recent studies indicate the need to interpret emergent shorelines in terms of middle and late Quaternary uplift (Bowden, 1978, 1981; van de Geer et al., 1979). The principal evidence bearing on the latter approach is discussed here. (Authors).

028 **BOWLES, D. S., and JAMES, D. L.** 1985. "Issues Associated with Stochastic Modeling of Great Salt Lake Levels for Planning Purposes," Problems of and for Predicting Great Salt Lake Levels Proceedings, Center of Public Affairs, Univ. of Utah, pp 218-235.

The rising level of the Great Salt Lake is having major impacts on the economy and on governments in Utah. Decision makers face uncertainties that scientific information can reduce. Principles from the physical sciences (meteorology, geology, hydrology, and physics), measured data (since 1843), and inferred information on prehistoric events must be combined with economic assessments. This paper presents the results of studies on probabilistic lake level forecasting and discusses issues of model reliability. A companion paper (James and Bowles 1985) describes how the probabilities can be used to optimize public lake-level-control and private lake-level-response investments. In combination, the papers identify some issues in model theory and data reliability to stimulate group discussion on research needs and management alternatives. (Introduction).

029 **BOYD, R., and PENLAND, S.** 1984. "Shoreface Translation and the Holocene Stratigraphic Record," Examples from Nova Scotia, the Mississippi Delta and Eastern Australia," B. Greenwood and R. A. Davis, Jr. (Editors), Hydrodynamics and Sedimentation in Wave-Dominated Coastal Environments. pp 391-412.

Classic descriptive models of barrier sedimentation have been developed with data from the Atlantic and Gulf coasts of the United States. These models are dominated by low to moderate rates of relative sea-level (RSL) rise and wave energy. Barriers respond by landward recycling of sediment through the mechanism of shoreface retreat. Sedimentation processes on the central coast of New South Wales (N.S.W.), Australia, consist of rapid RSL rise in early Holocene times followed by a stillstand since 6500 B.P. Wave energy is relatively high year-round and sand sources for barrier formation are only found on the inner shelf. Barrier sedimentation on the central coast of N.S.W. exhibits a thick, composite sequence composed of a basal marine transgressive sand overlain by regressive beach and dune facies.

The Louisiana coast surrounding the Mississippi delta is underlain by compacting deltaic muds which generate very rapid rates of RSL rise. The Louisiana coast experiences low wave energy punctuated by high-energy tropical and extra-tropical storm events. Barrier sediments accumulate from the erosion of deltaic headlands and undergo a transformation from subaerial barrier island systems to subaqueous shoals located on the inner shelf. Drumlins experience coastal erosion on the Eastern Shore of Nova Scotia and provide a sediment source for compartmented estuary mouth barriers. An ongoing, moderate rise of RSL results from the passage of a glacial forebulge. Wave energy is intermediate between Louisiana and N.S.W. and displays a seasonal pattern dominated by frequent winter storms. Coastal barrier sedimentation is episodic, consisting of a period of beach ridge progradation followed by barrier destruction and re-establishment further landward.

The three contrasting sedimentary sequences found in examples from Louisiana, N.S.W. and Nova Scotia indicate that presently available sedimentation models from locations such as the middle Atlantic or Texas coasts of the United States may only represent well-documented regional case studies. A true generalized coastal sedimentation model is required which can identify the parameters controlling vertical and horizontal translation of the depositional surface and provide relationships between these parameters which quantitatively predict the genesis, distribution and geometry of coastal sedimentary facies. (Authors).

030 BRAATZ, B. V., and AUBREY, D. G. 1987. "Recent Relative Sea-Level Change in Eastern North America," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., <u>Sea-Level Fluctuations and Coastal Evolution</u>, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 71-86.

Eigenanalysis of tide-gage records between 1920 and 1983 in eastern North America reveals highly variable spatial and temporal patterns of relative sea-level change. Auxiliary data from numerical modeling suggest that much of the long wavelength (thousands of kilometers) spatial patterns of sea-level change are due to postglacial isostatic adjustment of the land surface. Filtering the isostatic component from the rates of relative sea-level movement yields residual rates that fluctuate about a coastal mean of 1.0-1.5 mm/year during this 64 year time interval. This mean rate is within the range of previous estimates of mean rate of eustatic rise in sea-level during the past century. Some residual fluctuations (wavelengths of tens to hundreds of kilometers) correlate with tilts of the land surface revealed by geodetic leveling transects, and appear to be related to regional geology

(i.e., basement structures and tectonic provinces in Florida, Georgia, the Carolinas, and the Chesapeake Bay area; fault reactivation in northern New England and the Maritime Provinces). These results suggest that tide-gage data can be used to determine neotectonic movements along this coastline. Analysis of the temporal patterns of relative sea-level change reveals a gradual increase in the rate of rise centered at about 1934, which may be due to steric expansion of the ocean. Broad peaks in the spectrum of temporal sea-level fluctuations at 3, 6, and 20 year periodicities (significant at the 80 percent level) may be a reflection of oceanographic, atmospheric, and lunar forcing. (Authors).

031 BROOKES, I. A., SCOTT, D. B., and McANDREWS, J. H. 1985. "Postglacial Relative Sea-Level Change, Port au Port area, West Newfoundland," <u>Canadian Journal of Earth Sciences</u>, Vol 22, No. 7, pp 1039-1047.

Based on pollen and foraminifera analyses and radiocarbon dates from two cores taken from salt-marsh deposits bordering Port au Port Bay, southwestern Newfoundland, results show that relative sea-level (RSL) stood at 2.8 m below present higher high-water level (HHWL) at 2770 ± 300 years BP and at 1.8 m at 2365 ± 175 years BP at the core sites. These samples indicate a rate of late Holocene RSL change from western Newfoundland. We then report other available dates bearing on the earlier RSL record of this area.

A date of 5800 ± 200 years BP fixes the age of minimum RSL in Port au Port Bay at 11-14 m below present. A date of 9350 ± 120 years BP from St. George's provides a minimum age for the passage of sea-level below present there. A date 12,600 ± 140 years BP from Stephenville fixes a sea-level at 29 m above present, whereas one of 13 600 ± 110 years BP from Abrahams Cove dates the marine limit at 44 m. These geographically restricted data closely constrain a curve of postglacial RSL change in the Port au Port Bay - northern St. George's Bay area. The form of the curve supports a recent model predicting sea-level response to wastage of a limited late Wisconsinan ice load in the wider region. (Modified Abstract).

032 BROOKS, D. A. 1977. "Sea-Level Fluctuations Off the Carolina Coasts and Their Relation to Atmospheric Forcing," Center for Marine and Coastal Studies, North Carolina State University, Raleigh, North Carolina, pp 38.

Atmospheric pressure and wind stress fluctuations are strongly coupled to sea-level fluctuations along the Carolina coasts at periods of 2.5 to 3.5 days. Sea-level fluctuations in this band exhibit high coherence over a horizontal separation exceeding 500 km. Phase difference calculations indicate southward propagation of the sea-level fluctuations from Beaufort to Wilmington, North Carolina; the data considered are insufficient to conclusively determine propagation direction south of Wilmington. The 2.5 - 3.5 day period sea-level fluctuations are consistent with a theoretically expected first mode, barotropic continental shelf wave. It is concluded that continental shelf waves forced by the atmosphere contribute to the shelf and slope water circulation off North Carolina. (Author).

033 BROOKS, D. A. 1984. "Current and Hydrographic Variability in the Northwestern Gulf of Mexico," Journal of Geophysical Research, Vol 89, No. C5, pp 8022-8032.

From July 1980 to February 1981, ten current meters on three moorings were developed in the 200 to 700 m depth range over the continental slope in the northwestern Gulf of Mexico. The currents were characterized by energetic fluctuations with time scales of a week to several months. Westward drifting Loop Current anticyclones provided the principal driving mechanism for the fluctuations. Longshore current speeds at the 200-m depth occasionally exceeded 70 cm/s and were persistently >50 cm/s during a 2-month period in the fall. Except during a hurricane, the currents were only marginally coupled with the winds measured at Brownsville, Texas. Tidal motions accounted for <1% of the current variance. (Author).

034 BRUUN, P. 1962. "Sea-level Rise as a Cause of Shore Erosion," American Society of Civil Proceedings, Vol 88, Paper 3065, Journal of Waterways and Harbors Division, No. WW 1, pp 117-130.

This classical paper presents the Bruun Rule which defines the influence of sea level on the development of beach and offshore profile in quantitative terms. Bruun also discusses quantitative estimates of erosion along Florida beaches as a case study and the engineering implications of shoreline recession. (Gorman).

035 BRUUN, P. 1983. "Review of Conditions for Uses of the Bruun Rule of Erosion," Coastal Engineering, Vol 7, pp 77-89.

The Brunn Rule of erosion, so named by American coastal geomorphologists (Schwartz 1967) was first published in 1962 (Brunn, 1962) and briefly concerns a long-term budget of onshore/offshore movement of material. The rule is based on the assumption of a closed material balance system between the (1) beach and nearshore and (2) the offshore bottom profile. Figure 1 is a schematic of the effect, a translation of the beach profile by a distance s following a rise a of the sea-level, resulting in a shore erosion and a deposition of sediments. This topic is dealt with extensively in theory (Hallermeier 1972; Allison 1980; Bruun 1980) and through observations in the field (Bruun 1954 a, b, 1962, 1980; Dubois 1976; Rosen 1978, 1980; Weggel 1979; Fisher 1980; Hands 1980). The "rule" has sometimes been used rather indiscriminately without realizing its limitations. One should always remember that it is basically two-dimensional, but it is almost always applied three-dimensionally.

The background of this paper is to discuss boundary conditions and to make adjustments which make the rule more "practical" or realistic. (Author).

036 BRUUN, P. 1988. "The Bruun Rule of Erosion by Sea-Level Rise: A Discussion on Large-Scale Two- and Three-Dimensional Usages," Journal of Coastal Research, Vol 4, No. 4, pp 627-648.

This article reviews all basic assumptions for proper use of the Bruun-Rule of erosion by sea-level rise. It disproves misuses and discusses expansions of the rule's applicability in large-scale two and three dimensions. (Author).

037 BRUUN, P., and SCHWARTZ, M. L. 1985. "Analytical Predictions of Beach Profiles Change in Response to a Sea-Level Rise," Zeitschrift fuer Geomorphologie, Neue Folge, 57, pp 33-50.

Recent studies predict a sea-level rise of the order of 0.5 to 3.5 m by the year 2100. Beach profile translation and coastal erosion will, in most cases, accompany the rising level of the sea. Calculations for estimating potential erosion on a sandy shore are described. (Authors).

038 BRYAN, K., and SPELMAN, M. J. 1985. "The Ocean's Response to a CO_2-Induced Warming," Journal of Geophysical Research, Vol 90, No. C6, pp 679-688.

The climate response to a large increase in atmospheric CO_2 was investigated in a numerical experiment with a coupled ocean-atmosphere model. The study is focused on one aspect of the experiment, the predicted response of the ocean to the warming episode. A fourfold increase in atmospheric CO_2 causes a warming sufficiently intense to produce a partial collapse of the thermohaline circulation of the ocean. Surprisingly, the wind-driven circulation of the ocean is maintained without appreciable change. The global hydrological cycle intensifies without a major shift of the pattern of net precipitation over the model ocean. In the warming episode the downward pathways for heat, which include diffusion and Ekman pumping, remain open. The partial collapse of the thermohaline circulation closes the normal upward pathways associated with abyssal upwelling and high-latitude convection. As a result the thermocline is able to sequester almost twice as much heat than would be predicted from the behavior of a neutrally buoyant tracer introduced at the surface under normal climatic conditions. An enhanced sequestering of heat would produce a negative feedback for greenhouse warming. However, the partial collapse of the thermohaline circulation found in the numerical experiment would also affect the global carbon cycle, possibly producing a climatic feedback as strong as that caused by an enhanced uptake of heat from the atmosphere. (Authors).

039 BRYANT, E. 1983. "Regional Sea-Level, Southern Oscillation, and Beach Change; New South Wales, Australia," Nature, London, Vol 305, No. 5931, pp 213-216.

Coastal erosion is a problem of increasing concern that affects 60% of the world's sandy coastline. This erosion has been attributed to increased storminess, tectonic subsidence, eustatic sea-level rise, decreased shoreward sediment movement from the shelf, permanent longshore leakage of sediment from beach compartments, shifts in global pressure belts resulting in changes in the directional component of wave climates, and human interference. No one explanation has worldwide applicability because all factors vary regionally in importance. Evaluation of factors is complicated by a lack of accurate continuous, long-term erosional data. Historical map evidence spanning 100-1000 year has been used in a few isolated areas; however, temporal resolution has not been sufficient to evaluate the effect of climate variable. Air photographic evidence is restricted to the past 40 year and often suffers from insufficient ground control for accurate mapping over time. Ground surveying of beaches was rarely conducted before 1960 and is often discontinuous in time and space. The author resolved the problems of temporal and spatial continuity by studying change for the whole of Stanwell Park beach, N.S.W., Australia, for the period 1895-1980. By using the average high-tide wave run-up position measured accurately to ± 2.5 m from oblique and vertical photographs, changes could be linked to regional sea-level variation and a globally significant climatic variable, the Southern Oscillation (SO). (Author).

040 BURKE, C. D. 1987. "The Effects of Late Quaternary Climatic Changes and Glacioisostatic Rebound on Lake Level Fluctuations and Benthos of Lake Michigan," Palaios, Vol 2, pp 514-522.

Past lake stages of Lake Michigan are the result of water level still-stands and fluctuations initiated by the withdrawal of the Wisconsin glacial ice sheet (approximately 10,000-5,000 years before present). Dominance diversity, evenness, and community profiles were used to determine the effects of these fluctuations on ostracode populations and to reconstruct the paleo-environment of glacial Lake Michigan.

Results indicate that ostracode community diversity was low, and evenness was high during this period. Few species of ostracodes could tolerate the cold temperatures and oligotrophic conditions of the prehistoric lake system. This assemblage consists of Candona subtriangulata and C. crogmaniana.

Community profiles changed with fluctuations in water level. One significant change in diversity indices is recorded between the oldest lake stage (Alonquin) and the stratigraphically overlying, shallowest stage (Chippewa). Increase in diversity was probably a result of increasing nutrient availability and salinity, two by-products of erosional processes and evaporation initiated when the lake level declined and the climate warmed. These changes in diversity and abundance may imply an increase in primary productivity.

As much as 32% of lake-bottom sediments were exposed during the Chippewa water level minimum. This exposure of land and the resulting decrease in lake surface may have affected local and regional climate.

Glacioisostatic rebound of channel openings caused the lake level to rise to an extreme high (Nipissing stage). With increasing water levels, ostracode profiles changed and suggest that the hypolimnion decreased in

salinity and dissolved O_2. Although statistical analysis of diversity indices does not support significant changes in the environment between Winnetka and Lake Forest Members, this analysis may have been biased by small sample numbers. (Author).

041 BURKE, K., and CELAL SENGOR, A. M. 1988. "Ten Metre Global Sea-Level Change Associated with South Atlantic Aptian Salt Deposition," Marine Geology, Vol 83, pp 309-312.

Catastrophic filling of the kind of sub-sea-level depression commonly formed during ocean opening and ocean closing is the only mechanism, other than glacial eustasy, capable of rapidly lowering sea-level (i.e., within 10^3 - 10^4 years). Aptian evaporites overlying oceanic crust on both sides of the South Atlantic between the Walvis Ridge and the Niger Delta were deposited in such a basin by repeated spilling of ocean water. The final flooding of the South Atlantic north of the Walvis Ridge extracted about 14 X 10^8 km^3 of sea water from the world ocean and effected about 10 m. A corollary of our interpretation is that if the catastrophic sea-level lowerings during the Mosozoic era have amplitudes substantially greater than 10 m (e.g.,~ 100 m), then a glacial mechanism to explain them would seem inescapable although the stratigraphic record has not yet yielded any evidence of such glaciation. (Authors).

042 BUTTNER, P. J. R. 1987. "The Barrier System of the South Shore of Long Island, New York, U.S.A.; Response to the Expected Rise in Sea-Level," Northeastern Environment Science, Vol 6, No. 1, pp 1-22.

Rapid and systematic changes characterize the history of the barrier beaches and islands of Long Island. Several long-term trends are clear: first, westward-drifting littoral currents, flowing past the barrier beaches and islands of Long Island's south shore, are causing the entire barrier system to relocate downdrift (migration). At the same time, the barrier system is responding to the gradual rise in sea-level by moving landward (translocation). As a result, the actual shoreline is recessing (moving landward) at an average of about three ft per year. (Modified Abstract).

043 BIRYUKOV, V. Y., FAUSTOVA, M. A., KAPLIN, P. A., PAVLIDIS, Y. A., ROMANOVA, E. A. and VELICHKO, A. A. 1988. "The Paleogeography of Arctic Shelf and Coastal Zone of Eurasia at the Time of the Last Glaciation (18,000 year BP)," Paleogeography, Palaeoclimatology, Palaeoecology, Vol 68, No. 2-4, pp 117-125.

Paleogeographic maps showing reconstructed environments of the Eurasian Arctic shelf and coastal zone during the last glacial maximum were compiled. The reconstruction shows conspicuous difference between eastern and western sectors of the Arctic shelf of Eurasia. Large glaciers existed in the west while the eastern Arctic shelf was an emerged ice-fee lowland dominated by

tundra landscapes and built of unconsolidated sediments with a variety of genesis. (Authors)

044 **CANE, M. A., and ZEBIAK, S. E.** 1985. "A Theory for El Niño and the Southern Oscillation," Science, Vol 228, pp 1085-1087.

A coupled atmosphere-ocean model is presented for El Niño and the Southern Oscillation that reproduces its major features, including its recurrence at irregular intervals. The interannual El Niño-Southern Oscillation cycle is maintained by deterministic interactions in the tropical Pacific region. Ocean dynamics alter sea-surface temperature, changing the atmospheric heating; the resulting changes in surface wind alter the ocean dynamics. Annually varying mean conditions largely determine the spatial pattern and temporal evolution of El Niño events. (Authors).

045 **CARRERA, G., and VANICEK, P.** 1988. "A Comparison of Present Sea-Level Linear Trends From Tide Gage Data and Radiocarbon Curves in Eastern Canada," Paleogeography, Palaeoclimatology, Palaeoecology, Vol 68, No. 2-4, pp 127-134.

A comparison is made of the results for determinations of vertical crustal movements by means of two independent sources of data widely used in geodesy and geology: tide gage sea-level linear trends and gradients of radiocarbon curves. As a reference, the map of vertical crustal movements of canada is added which was computed using not only tide gage data but also geodetic levelling data. These results show similar trends computed by both techniques but an average value of 0.1 m/century greater for the sea-level trends. (Authors).

046 **CARTER, W. E., ROBERTSON, D. S., PYLE, T. E., and DIAMANTE, J.** 1986. "The Application of Geodetic Radio Interferometric Surveying to the Monitoring of Sea-Level," Geophysical Journal of the Royal Astronomical Society.

Under project IRIS (International Radio Interferometric Surveying) geodesists are using Very Long Baseline Interferometry (VLBI) to monitor polar motion to 1-2 milliseconds of arc and UT1 to .05-0.10 milliseconds, and to develop a global geodynamic network to detect and study centimeter level displacements of reference points associated with large scale phenomena such as tectonic plate motion and glacial rebound. Differential positioning techniques using the signals broadcast by the satellites of the Global Positioning System (GPS) are being used to study finer scale phenomena such as localized subsidence, and to economically relate these specialized surveys to the geodynamic network. Including tide gage stations in this system will make it possible to detect motions of specific gages and correct or delete the measurements from those gages when computing changes in sea-level. The National Oceanic and Atmospheric Administration (NOAA) has selected several tide gages on the east and west coast of the United States, and initial epoch GPS surveys to tie the gages to VLBI observatories have already begun. Other countries participating in project IRIS are planning similar activities. In addition to

providing a globally based land reference datum for the tide gage measurements, the IRIS polar motion and UT1 time series may contribute directly to monitoring and interpreting global sea-level changes. Changes in the volume and distribution of ice masses result in long term motions of the axis of rotation, and sea-level changes affect the length of day (lod). The IRIS time series will certainly have the resolution required to detect the expected polar motion and changes in load, and a properly designed global VLBI/GPS network should allow the ice/sea-level effects to be separated from crustal dynamics effects. (Authors).

047 **CARTWRIGHT, D. E., BARNETT, T. P., GARRETT, C. J. R., CARTER, W. E., PESTAER, R., PYLE, T., and THOMPSON, K. R.** 1985. "Changes in Relative Mean Sea-Level," EOS Transactions, American Geophysical Union, Vol 66, pp 754-756.

After some decades of comparative neglect, changes in mean sea-level relative to land (R.S.I.) are now appreciated by oceanographers and geophysicists as an important integral parameter of ocean climate and vertical land movement that is fairly easy to measure for long periods. Interest has been raised by the relevance of RSL to "El Niño" events, as shown by the new Pacific island network operated by the University of Hawaii, and by several studies of recent secular rise in global RSL in relation to changes in temperature and glaciation. Monthly RSL maps for the entire tropical Pacific are currently issued in near real time by the Integrated Global Ocean Station System Sea-Level Pilot Project. A global network of tide gage stations has recently been proposed by the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific, and Cultural Organization in support of the Tropical Ocean Global Atmosphere (TOGA) and World Ocean Circulation Experiment (WOCE) campaigns. International symposia on RSL were staged at the 1984 AGU Fall Meeting and at the International Association of Meteorology and Atmospheric Physics (IAMAP) International Association for Physical Sciences of the Ocean (IAPSO) Joint Assembly in Hawaii, August 1985.

A panel of seven experts, the authors of this paper, met in Halifax, Canada, in March 1985, and decided to address the following questions: In trying to interpret secular changes in RSL from an array of tidal stations, which of the many contributing climatological and geodynamic factors should be taken into account? What other measurements should be made to aid interpretation? Finally, are there reasonable strategies for distribution of new tidal stations, other than an evenly distributed global spread? Although the prime interest here is in very low frequency phenomena, we believe that these questions require study of the response of sea-level at much higher frequencies, where other forcing agents besides air temperature and tectonics are dominant.

What follows is a series of related accounts of various aspects of the above problem on which the LAPSO Advisory Committee on Tides and Mean Sea-level considered itself to be authoritative, in general starting with low-frequency phenomena and proceeding toward changes in RSL at subannual periods. We realize that there are other urgent needs for sea-level monitoring on, for example, infra-annual time scales, where secular changes over a century are of no consequence. Such applications are already well discussed in the literature on say, equatorial ocean dynamics or satellite altimetry. We have not tried to give a comprehensive review but have

preferred to approach the subject from what we believe to be an original viewpoint. (Introduction).

048 **CATALLO, W. J., THEBERGE, N. B., and BENDER, M. E.** 1989. "Sea-Level Rise and Hazardous Wastes in the Coastal Zone: An Ecological Perspective," Proceedings of Coastal Zone '89, Vol 2, pp 1407.

Over the past five years, concern regarding probable changes in eustatic sea-level in response to global warming-greenhouse effect has given rise to a flurry of attempts to integrate varied geophysical data into a solid predicative framework. Recent predictions of global sea-level rise by year 2100 have ranged between 0.5 - 3.5, with 1.5 m being a good working estimate for scientists and coastal managers, even though this is bound to be revised in light of new data. A rise in sea-level of this magnitude would greatly impact the current coastal zone through erosion and breaching of barrier islands, salt intrusion, wetland destruction and vegetative displacement, topsoil erosion and sediment translocation offshore, changes in weather patterns and hydrologic cycle, and increased inland range of tides and marine storms. Although the social, legal, and environmental implications of such events have yet to be grasped fully, attempts have been made to construct conceptual models that consider these large scale effects as well as "regional" concerns ranging from the necessity of exhuming the dead in threatened coastal areas to the human health implications of increasing temperature and water cover in temperate regions. Much of this work is of great value, however, the effects of sea-level rise on containment of hazardous wastes in coastal dumpsites, landfills, and subsurface containers has received very little attention in the technical literature. A review of the models and recommendations of this literature indicates that the magnitude and scope of hazardous wastes in the coastal zone have not been appreciated or thought through. The U.S. generates approximately 170 million tons (MT) of solid and 275 - 1000 MT of hazardous waste annually. Of the nearly 800 final sites on the U.S. Environmental Protection Agency (USEPA) National Priority List (NPL) for Superfund cleanup, which were selected from a proposed list of 29,000, approximately 75% are in coastal states. A random sampling of coastal plain states indicates that 25 - 60% of the NPL sites occur in or near estuarine, riparian, or coastal lowland ecosystems. These estimates do not include private or unauthorized. (Authors).

049 **CATON, P. W.** 1973. "The Surtsey Pond: Determination of Mean Sea-Level," unpublished Ph.D Dissertation, University of Tulsa, Tulsa, Oklahoma, pp 194.

Tidal fluctuations of inshore ponds separated from the ocean by a sand bar are investigated. The pond fluctuations are reduced in amplitude and delayed in time relative to the ocean oscillations. The aquifer configuration and the shape of the pond produces asymmetric oscillations in the pond whereby the average pond level differs somewhat from the average sea-level.

Mathematical models are used to describe the flow of water in an unconfined aquifer between the ocean and the tidal pond. These models assume

horizontal laminar flow and boundary conditions that include harmonic oscillations of the ocean, sloping beaches of both ocean and pond, and a horizontal lower boundary of the permeable sand bar. Laboratory models (sandbox models) were used to test the reliability of the assumptions made in the mathematical models.

The tidal fluctuations of a pond near the north shore of the new volcanic island, Surtsey, off the south coast of Iceland, were measured in August, 1967. The pond amplitudes were about 0.56 of the ocean amplitudes and the peak and trough delays were established to be 138 and 165 minutes respectively. This asymmetrical response indicates that the mean pond level is different from the mean sea-level. A mathematical flow model that gave good agreement with the observed pond oscillations had a circular conical pond of 60 ms radius at mean sea-level and a 3 m depth with a 130 m wide circular sand bar between the pond and the ocean. The required porosity of the sand was about 0.4 and the effective permeability 2.5 cm/sec. The average depth to the base of the permeable sand was set at 5 ms. These conditions required the mean pond level to be 4 cm above mean sea-level. (Author).

050 **CHELTON JR., D. B.** 1980. "Low Frequency Sea-Level Variability Along the West Coast of North America," unpublished Ph.D Dissertation, University of California, San Diego, CA, pp 212.

The use of linear statistical estimators to examine dynamical models is discussed and the importance of using multiple input statistical models rather than a series of single input models is emphasized. A methodology is described for determining the effects of statistical uncertainty in both time and frequency domain multiple input statistical models. These methods are then used to examine 30 years of nonseasonal tide gage and steric sea-level data along the west coast of North America. The objective is to explore the nature and causes of nearshore oceanic variability over short term climatic time scales of months to years.

After the tide gage records are corrected for the inverse barometric effects of atmospheric pressure, it is found that there is close agreement between the two measures of sea-level at frequencies less than 1 cycle/year. At higher frequencies the steric sea-level variations measured relative to 500 db are on average, only about 1/2 as large as high frequency tide gage sea-level variations. Higher frequency variations are primarily the result of forcing by the local atmospheric pressure but the response is generally found to be greater than inverse barometric (1 cm/mb). Much of the remaining frequency sea-level variability is the result of forcing by the wind field. The longshore component of wind stress generally forces a larger sea-level response than the onshore component but the important dynamical aspects of the wind field generally appear to be basin wide rather than local.

The dominant signal in residual sea-level after removing the atmospheric and oceanographic effects as determined from the statistical models represents long term trends over the 30 year record length. The trends at the lower latitude stations are attributed to the eustatic rise in sea-level from melting glaciers. The drop in measured sea-level at the higher latitudes has generally been attributed in the past to an apparent drop due to isostatic rebound of the earth's crust from the most recent glaciation. However, it is

shown that part of this drop may reflect a true change in sea-level due to cooling of the surface waters in the North Pacific over the last 30 years.

Analyzing steric sea-level records off California it is found that the hydrographic data is quite noisy but that empirical orthogonal function analysis is an effective method for extracting the large scale "signal" from the mesoscale "noise." Most of the nonseasonal upper ocean variability is restricted to the upper 200 ms but located subsurface at about the depth of the permanent thermocline. The dominant signal in nonseasonal nearshore oceanic variability is a very large scale low frequency variation in the flow with biological effects off the coast of California similar to those of Southern Hemisphere El Niño events off the coast of Peru and southern Ecuador. Over shorter time scales the wind stress curl appears to be an important aspect of large scale dynamics of the California Current. In addition, another mode of high frequency variability with very short longshore coherence is isolated that resembles the response expected for coastal upwelling driven by the longshore wind stress. (Author).

051 **CHELTON, D. B., and DAVIS, R. E.** 1982. "Monthly Mean Sea-Level Variability Along the West Coast of North America," Journal of Physical Oceanography, Vol 12, No. 8, pp 757-784.

Linear statistical estimators are used to examine 29 years of nonseasonal, monthly-mean, tide gage sea-level data along the west coast of North America. The objective is exploration of the structure and causes of nearshore ocean variability over time scales of months to years at 20 stations from Alaska to Mexico. North of San Francisco, 50-60% of the sea-level variability reflects a simple inverse barometric response to local atmospheric pressure. There inverted barom effects account for only 10-15% of the variance at stations to the south.

The dominant signal of inverse-barometer-corrected sea-level represents a nearly uniform rise or fall of sea-level everywhere along the eastern rim of the North Pacific. The interannual aspects of this large-scale sea-level variability are closely related to El Niño occurrences in the eastern tropical Pacific which appear to propagate poleward with phase speeds of ~40 cm s^{-1}. Higher frequency aspects of this large-scale sea-level variability appear to represent quasi-geostrophic currents driven by basin-wide scales of wind forcing over the North Pacific.

The nature of local (individual station) inverse-barometer corrected sea-level variability is examined through a series of statistical models and the results are compared with existing dynamical models. The longshore component of wind stress generally forces a larger response than the onshore component (except in large semi-enclosed basins) but the important dynamical aspects of the wind field appear to be basin wide rather than local. The response is consistent with that expected from Ekman dynamics. An apparent non-barometric response to local atmospheric pressure is shown to partly represent an influence of sea-level anomalies farther south. Efforts to determine the nature of this indirect coupling between local pressure and sealevel at stations to the south are somewhat limited by the ability of statistical estimators to accurately isolate the responses of sea-level to a number of correlated inputs. However, evidence is presented indicating that part of the apparent non-barometric response is due to longshore wind-stress

forcing at stations to the south. A response 30-50% greater than inverse barometric remains unexplained from Tonno to San Francisco. (Authors).

052 **CHOWDHURY, J. K.** 1989. "Effect of Global Temperature Rise on the Coastlines of Bangladesh," Magoon, O. T., Converse, H., Miner, D., Tobin, L. T. and Clark, D., eds., Proceedings of Coastal Zone '89, American Society of Civil Engineers, Vol 2, pp 1360-1369.

Accumulation of CO^2 in the earth's atmosphere due to ever increasing use of fossil fuel is threatening the delicate balance of the earth's climate. This imbalance could change our climate similar to conditions that existed 4,000 to 8,000 years ago by the middle of next century. Such a drastic climatic change in such a short time would negatively effect all of us in this planet. These effects could be catastrophic to the coastal low lying areas. One of the most devastating effect could take place in Bangladesh due to its geographic location and geomorphic conditions. (Modified Abstract).

053 **CISNE, J. L., and GILDNER, R. F.** 1988. "Measurement of Sea-Level Change in Epeiric Seas," The Middle Ordovician Transgression in the North American Midcontinent", Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C.A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 217-226.

Carbonate sediments of tectonically quiescent continental interiors are nearly ideal for precisely tracing eustatic sea-level change during major transgressions. Over roughly 10 million years during the later Middle Ordovician (Rocklandian through the middle Denmarkian stages), sea-levels measured in the American Midwest rose about 10 m relative to the continent. Because the sediment accumulation rate in the epeiric sea was proportional to water depth, the time trend of sea-level can be reconstructed from cumulative sediment thickness and from measurements on water depth throughout a stratigraphic section. Sea-level is reconstructed as a function of time for six sections in the midwestern United States, and the reconstructed time trends are compared for common eustatic components based on the section time correlations by geochemically fingerprinted volcanic-ash layers. Relative water depth is measured through gradient analysis of fossils assemblages by reciprocal averaging ordination. Sample ordination scores are calibrated as a measure of absolute depth by use of the offshore depth estimated from stratigraphic expressions of the shoreline edge effect in lithospheric flexure. Sea-level change during the Middle Ordovician transgression had at least two components: (1) a steady rise at slowly varying rate around 1 m per million years (2) pulses no more than 0.1 to 1 million years long during which sea-level fell roughly 1 m and then rose about the same amount. The long-term trend is attributable to steady decrease in the mean age of oceanic lithosphere. The pulse correlations from section to section and the remarkably small sea-level changes involved testify to the tectonic quiescence, spatial homogeneity, and essential tidelessness of the epeiric sea, and to the precision of its stratigraphic record. Pulses were probably

related to climatic fluctuations, and their association with particularly frequent volcanic-ash deposition is suggestive that climatic effects of increased explosive volcanism may have been controlling factors. (Authors).

054 **CLARK, J. A., FARRELL, W. E., and PELTIER. W. E.** 1978. "Global Changes Post Glacial Sea-Level: A Numerical Calculation," Quaternary Research, Vol 9, pp 265-287.

The sea-level rise due to ice-sheet melting since the last glacial maximum was not uniform everywhere because of the deformation of the Earth's surface and its geoid by changing ice and water loads. A numerical model is employed to calculate global changes in relative sea-level on a spherical viscoelastic Earth as northern hemisphere ice sheets melt and fill the ocean basins with meltwater. Predictions for the past 16,000 years explain a large proportion of the global variance in the sea-level record, particularly during the Holocene. Results indicate that the oceans can be divided into six zones, each of which is characterized by a specific form of the relative sea-level curve. In four of these zones emerged beaches are predicted, and these may form even at considerable distance from the ice sheets themselves. In the remaining zones submergence is dominant, and no emerged beaches are expected. The close agreement of these predictions with the data suggests that, contrary to the beliefs of many, no net change in ocean volume has occurred during the past 5000 years. Predictions for localities close to the ice sheets are the most in error, suggesting that slight modifications of the assumed melting history and/or the rheological model of the Earth's interior are necessary. (Authors).

055 **CLARK, J. A. and LINGLE, C. S.** 1977. "Future Sea-Level Changes Due to West Antarctic Ice Sheet Fluctuations," Nature, Vol 269, pp 206-209.

Global sea-level changes which would result from an instantaneous uniform thinning of the possibly unstable West Antarctic ice sheet are calculated and found to be nonuniform. At locations distant from the ice sheet (Hawaii, New York, the North Sea), immediate submergence would be followed by gradual additional submergence, then slow emergence. At New Zealand, immediate submergence would be followed by gradual additional submergence, then slow emergence would begin 2,500 year. At locations close to the ice sheet (Cape Horn, the Ross Ice Shelf), the sea-level would fall for 1,100 year, then rapid submergence would start resulting in a net sea-level rise after 10,000 year equal to about 92% of the average global rise. (Authors).

056 **CLARK, J. A. and LINGLE, C. S.** 1979. "Predicted Relative Sea-Level Changes (18,000 years B.P. to present) Caused By Late-Glacial Retreat of the Antarctic Ice Sheet," Quaternary Research, Vol II, pp 279-298.

Predictions of global changes in relative sea-level caused by retreat of the Antarctic Ice Sheet from its 18,000 year B.P. maximum to its present size are calculated numerically. When combined with the global predictions of relative sea-level change resulting from retreat of the Northern Hemisphere ice sheets, the results may be compared directly to observations of sea-level change on the Antarctic continent as well as at distant localities. The comparison of predictions to the few observations of sea-level change on Antarctica supports the view that the Antarctic Ice Sheet was larger 18,000 years ago than at present. The contribution of the Antarctic Ice Sheet to the total eustatic sea-level rise is assumed to be 25 m (25% of the assumed total eustatic rise). If as little as 0.7 m of this 25 m rise occurred between 5000 year B.P. and the present, few mid-oceanic islands would emerge. If the Antarctic Ice Sheet attained its present dimensions by 6000 year B.P. however, and if the volume of the ocean has remained constant for the past 5000 years, numerous islands throughout the Southern Hemisphere would emerge. It is suggested that a thorough study of Pacific islands, believed by some to have slightly emerged shorelines of Holocene age, would yield useful information

about ocean volume changes during the past 5000 years, and hence on the glacial history of the Antarctic Ice Sheet. (Authors).

057 CLOETINGH, S. 1988. "Intraplate Stresses: A Tectonic Cause For Third-Order Cycles in Apparent Sea-Level?," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 19-30.

Thermo-mechanical modeling demonstrates that tectonically induced vertical motions of the lithosphere may provide an explanation for third-order cycles in apparent sea-level deduced from the seismic stratigraphic record of passive margins. The interaction of fluctuations in intraplate stresses and the deflection of the lithosphere caused by sedimentary loading can produce apparent sea-level changes of as much as 100 m at the flanks of passive margins.

In general, stress variations of a few hundred bars associated with local adjustment of stresses at passive margins suffice to explain a significant part of the stratigraphic record associated with short-term variations in sea-level on the order of a few tens of ms. To induce short-term apparent sea-level fluctuations with magnitudes on the order of 50 m or more, which occur less frequently in the record, changes in stress level in excess of one kbar are required. These larger fluctuations in apparent sea-level could be related to major reorganizations of lithospheric stress fields due to rifting and fragmentation of plates, dynamic changes at convergent plate boundaries, of collision processes. A fluctuating horizontal stress field in the lithosphere can explain contemporaneous changes in apparent sea level in neighboring depositional environments. In principle, it implies the possibility of regional correlations in different basin settings. Specific short-term fluctuations in the curves of Vail and others can be associated with particular plate tectonic reorganizations of lithospheric stress fields. The seismic stratigraphic record may provide a new source of information on

paleostress fields which can be correlated with results of independent numerical modeling of intraplate stresses. (Modified Abstract).

058 COLMAN, S. M., and MIXON, R. B. 1988. "The Record of Major Quaternary Sea-Level Changes in a Large Coastal Plain Estuary, Chesapeake Bay, Eastern United States," Palaeogeography, Palaeoclimatology, Palaeoecology, Vol 68, No. 2-4, pp 99-116.

Seismic-reflection surveys of the Chesapeake Bay, combined with geologic mapping and analysis of boreholes on the Delmarva Peninsula, provide evidence of at least three generations of the Susquehanna River system and three generations of the Chesapeake Bay. The evidence for ancient courses of the Susquehanna River is preserved as three distance paleochannels, and evidence for ancient versions of the Chesapeake Bay is preserved as three sets of paleochannel fill beneath the bay and three generations of barrier-spit deposits on the southern Delmarva Peninsula. A history of three major marine transgressions is recorded in the stratigraphy preserved in the filled paleochannels and in the overlying barrier-spit complexes: three systematic progressions from fluvial to estuarine to bay or nearshore marine environments. The three paleochannel-fill and barrier-spit complexes appear to corresponds to oxygen-isotope stages 1, 5, and either 7 or 11; the three related paleochannels correspond to stages 2, 6, and either 8 or 12. (Authors).

059 COLEMAN, J. M. and SMITH, W. G. 1964. "Late Recent Rise of Sea-Level," Geological Society of America, Bulletin 75, pp 833-840.

Radiocarbon dating of marsh peats in south-central Louisiana permits interpretations of relationships between former positions of land and sea. Past marsh surfaces, now buried at depths ranging from 4 to 40 ft, indicate the positive change in level that has taken place since their origin. Abundant evidence for a stillstand in sea-level during the past 2000-5000 years affords a fixed datum for differentiation between eustatic sea-level rise and subsidence in the study area is 0.24 ft per century. Results show a eustatic sea-level was higher than at present at any time during the interval studied. (Authors).

060 CRONIN, T. M. 1988. "Ostracods and Sea-Level Changes: Case Studies From the Quaternary of North and South Carolina, U.S. Atlantic Coast," Ostracoda in the Earth Sciences, pp 77-88.

Thirteen marginal marine ostracod species restricted to brackish water lagoonal, estuarine and salt marsh habitats of the US Atlantic coast were used for identifying palaeoshorelines and coastal environments. Marginal marine ostracod species were analyzed from two Quaternary sections from North and South Carolina for which reliable ages and palaeoclimatic data were available. The results indicated a general faunal pattern for several middle and late

Pleistocene high stands of sea-level. The implications of the Atlantic sea-level record for models of Quaternary sea-level change are discussed briefly. (Author).

061 **CROSS, T. A.** 1988. "Controls on Coal Distribution in Transgressive-Regressive Cycles, Upper Cretaceous, Western Interior, U.S.A.," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 371-380.

The thickest and most extensive Upper Cretaceous coals of the western interior of the United States occur at the top of, and landward of shoreface and delta front platforms that are stacked vertically. An explanation for this observation was sought through numerical models derived from the interactions of the three fundamental processes that control stratal geometries and lithofacies distributions. These are eustatic fluctuations, tectonic movement, and quantity of sediment delivered to or produced in a sedimentary basin.

The models show that the fundamental building block of marine-shelf to coastal-plain stratigraphic sequences is the progradational event as expressed in vertical profile as a shallowing-upward succession of facies asymmetry is modeled by sinusoidal sea-level oscillations superimposed on a constant rate of tectonic subsidence: disharmonic variations in either sea-level or tectonic movement are unnecessary to produce this asymmetry.

The models simulate a hierarchical stacking of progradational events that display three geometric patterns: seaward-stepping, landward-stepping, and vertical-stacking. The models show that the thickest and most extensive coals accumulate when accommodation space in the lower potentially coalbearing portion of the coastal plain is near maximum and when the rate of sea-level change is balanced by the rate of sediment supplied by progradational events. These factors result in vertical aggravation of coastal-plain facies tracts and vertical stacking of the progradational events. (Author).

062 **CURRAY, J. R.** 1961. "Late Quaternary Sea-Level: A Discussion," Geological Society of America, Bulletin 72, pp 1707-1712.

Recent literature and new evidence on the position of sea-level during the late Quaternary are reviewed critically. Some evidence suggests a glacial interstadial and stand of sea-level at about -8 fathoms 30,000 years ago. Sea-level then dropped to perhaps -65 fathoms. The rapid rise of sea-level and warming of climate covered a period of time from 15,000 to 7,000 B.P. (Before Present) and consisted of a period of climatic and sea-level fluctuations rather than a single abrupt warning as proposed for 11,000 B.P. (Author).

063 **DALY, R. A.** 1920. "Oscillations of Level in the Belts Peripheral to the Pleistocene Ice-Caps," American Association of Petroleum Geologists, Bulletin 31, pp 303-318.

Many lines of evidence seem to support Jamieson's suggestion that the earth's crust has been plastically deformed by glacial loading and in the reverse way, by unloading through the melting of icecaps. Study of the recently emerged zone in New England and of the specific distribution of plants and animals in Newfoundland indicate the probable existence of a late Glacial to Recent bulge of land near the edge of the continental shelf. If that bulge ("Georges Bank Land") were flattened because the glaciated area on the northwest rose in consequence of unloading (ice-melting), one may reasonably expect field evidences of similar peripheral subsidence west of New England. Deformed lake stands, the submarine channel of the Hudson River, the "deeps" of the Susquehanna River, and Pleistocene drainage rearrangements of the marginal belt west of New Jersey offer relevant topics for discussion. In no case can the evidence be regarded as final, for none can be discussed intelligently without making at least one unproved assumption. A leading and general difficulty lies in the uncertainty as to the position of the zero isobase corresponding to each subsidence and each uplift, respectively induced by glaciation and deglaciation. Jamieson's hypothesis thus leads to many questions without answers; precisely for that reason it has value if it stimulates further fieldwork by experts. Especially because of Munthe's positive results in Baltic lands, the hypothesis can not fail to be seriously and actively entertained in America. (Author).

064 **DEAN, R. G.** 1983. "Shoreline Erosion Due to Extreme Storms and Sea-Level Rise," Final Report R/T-24, Coastal and Oceanographic Engineering Department, Univ. of Florida, Gainesville, FL, pp 58.

A summary is presented of research conducted on beach erosion associated with extreme storms and sea-level rise. These results were developed by the author and graduate students under sponsorship of the University of Delaware Sea Grant Program.

Various shoreline response problems of engineering interest are examined. The basis for the approach is a monotonic equilibrium profile of the form $h = Ax^{2/3}$ in which h is water depth at a distance x from the shoreline and A is a scale parameter depending primarily on sediment characteristics and secondarily on wave characteristics. This form is shown to be consistent with uniform wave energy dissipation per unit volume. The dependency of A on sediment size is quantified through laboratory and field data. Quasi-static beach response is examined to represent the effect of sea-level rise. Cases considered include natural and sea-walled profiles.

To represent response to storms of realistic durations, a model is proposed in which the offshore transport is proportional to the "excess" energy dissipation per unit volume. The single rate constant in this model was evaluated based on large scale wave tank tests and confirmed with Hurricane Eloise pre- and post-storm surveys. It is shown that most hurricanes only cause 10% to 25% of the erosion potential associated with the peak storm tide and wave conditions. Additional applications include profile response employing a fairly realistic breaking model in which longshore bars

are formed and longterm (500 years) Monte Carlo simulation including the contributions due to sea-level rise and random storm occurrences. (Author).

065 **DAVIS, G. H.** 1987. "Land Subsidence and Sea-Level Rise on the Atlantic Coastal Plain of the United States," Environmental Geology and Water Science, Vol 10, No. 2, pp 67-80.

Land subsidence due to decline in head confined aquifers related to municipal and industrial water pumpage, is widespread in the Atlantic Coastal Plain. Although not a major engineering problem, subsidence greatly complicated adjustments of precise leveling and distorts prediction of future sea-level rise. When preconsolidation stress equivalent to about 20 m of head decline is exceeded, compaction of fine-grained sediment the aquifer system begins, and continues until a new head equilibrium is attained between fine and coarse units. The ration subsidence/head decline is quite consistent, ranging from 0.0064 in southeastern Virginia to 0.0018 at Dover, Delaware, and Atlantic City, New Jersey. (Authors).

066 **DAVIS, R. A., JR., and CLIFTON, H. E.** 1987. "Sea-Level Change and the Preservation Potential of Wave-Dominated and Tide-Dominated Coastal Sequences," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 167-180.

The relative change in sea-level and the rate of sediment input determine the character and the preservation potential of most coastal sequences, although wave and tidal energy, and geomorphic and geologic setting must also be considered. Progradational (regressive) coastal deposits are more likely to be fully preserved than those of transgressive coasts. Modern progradational coasts include numerous wave-dominated examples, (e.g., the Nayarit coast of Mexico, the Georgia Bight, and the Washington coast near the mouth of the Columbia River), and a few tide-dominated examples (e.g., the German Bight). In either situation, fairly complete shallowing-upward sequences of subtidal to supratidal facies are preserved, because the sedimentation rate exceeds dispersal by wave and/or tidal energy and the effect of rising or falling sea-level.

Transgressive sequences, which form where relative sea-level rise exceeds net sediment accumulation, differ in degree of preservation. Wave-dominated transgressive systems include the present coast of Delaware and the outer banks of North Carolina. The Colorado River delta in the Gulf of California represents a tide-dominated transgressive coast. Under wave-dominated conditions, slow transgression with abundant sediment input and moderate or low-incident energy will allow much of the sequence to be preserved. A transgressive tide-dominated coast that is associated with low sediment influx from land is characterized by shoreward transport of subtidal sediment over the pre-existing facies. Present coastal conditions also produce geographically juxtaposed progradational and transgressive sequences, as on drumstick barriers. Such situations would generate a complicated stratigraphic record. (Authors).

067 **DEAN, W. E., BRADBURY, J. P., ANDERSON, R. Y., and BARNOSKY, C. W.** 1984. "The Variability of Holocene Climate Change: Evidence From Varved Lake Sediments," Science, Vol 226, No. 4679, pp 1191-1194.

Varved sediments from a lake near the present forest-prairie border in northwestern Minnesota provide an annual record of climate change for the last 10,400 years. Climate-sensitive mineral, chemical, and biological components show that the mid-Holocene dry interval between 8,500 and 4,000 years ago is asymmetrical and actually consists of two distinct drier pulses separated by a moister interval that lasted about 600 years. Cyclic fluctuations with

periods of several hundred years were abrupt and persistent throughout the Holocene and are most clearly recorded within the two drier pulses. (Authors).

068 **DELAUNE, R. D., BAUMAN, R. H., and GOSSELINK, J. G.** 1983. "Relationships Among Vertical Accretion, Coastal Submergence, and Erosion in a Louisiana Gulf Coast Marsh," Journal of Sedimentary Petrology, Vol 53, No. 1, pp 0147-0157.

Vertical accretion in a southwest Louisiana *Spartina patens* brackish marsh has not kept pace with coastal submergence during the past three decades. The rate of accretion determined from 137 Cs dating and the use of artificial marker horizons averaged 0.8 cm/year., whereas coastal submergence obtained from tide-gage data averaged 1.2 cm/year. Conversion from marsh to open-water bodies closely paralleled the increase in coastal submergence. If resulting aggravation deficit continues, the marsh will likely complete its transformation to an open bay in less than 40 years. In view of recent projections of increasing sea-level rise and results presented may foreshadow a more widespread phenomenon. (Authors).

069 **DE MESQUITA, A. R., FRANCO, A. S. and HARARI, J.** 1986. "On Mean Sea-Level Along the Brazilian Coast," Geophysical Journal, Royal Astronomical Society, pp 67-77.

Fourier analyses of mean monthly sea-level data from Belem, Fortaleza, Salvador and Imbituba, ports on the Brazilian coast, are made with simultaneous data of air temperature, sea surface atmospheric pressure, atmospheric precipitation and evaporation. Results show that the mean monthly sea-levels of ports below Recife's latitude show peaks in February-March and April-May which are apparently related to the seasonal temperature changes and the combined action of precipitation, winds and oceanographic large-scale changes. The port of Belem showed a stronger semi-annual seasonal component, which seems to be related to the atmospheric precipitation. (Authors).

070 DEMAREST, J. M., II, and KRAFT, J. C. 1987. "Stratigraphic Record of Quaternary Sea-Levels: Implications for More Ancient Strata," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 223-240.

The stratigraphic record of Quaternary transgressions due to glacio-eustatic rise varies as a function of sediment supply from rivers to the paralic realm. Extremes from low to high sediment supply are represented by the Atlantic and Gulf coasts of the United States, respectively.

The vertical sequence produced by these transgressions at the low sediment supply end of the spectrum consists of paralic and fluvial lithosomes erosionally truncated by shoreface retreat and overlain by shelf marine lithosomes. The lithosomes produced in the landward portion of the paralic realm are commonly preserved, whereas the lithosomes from the foreshoreward part are less likely to be preserved. Thus, beach facies are rarely incorporated into the transgressive stratigraphic record, except as a peak sea-level deposit preserved by abandonment. Erosional truncation of the paralic section produces a unique stratigraphic surface, three ravinement surface, which exhibits many of the physical characteristics of a major break in deposition. The surface is then overlain by nearshore to offshore shelf facies in a deepening-upward succession.

When encountered in the stratigraphic record, the ravinement surface is likely not to be interpreted as a depositional sequence boundary. When this occurs, a continuous cycle of deposition during transgression is not recognized. When a ravinement and its associated facies are properly interpreted, a complete cycle of transgression and regression in response to changing sea-level can be recognized. (Authors).

071 DEMIRPOLAT, S., and TANNER, W. F. 1987. "Advanced Grain Size Analysis and Late Holocene Sea-Level History," Proceedings of Coastal Sediments '87, Vol 2, pp 1718.

Details of the history of changes in mean sea-level, average wave conditions and storminess, for the most recent 3,000-5,000 years, can be deciphered in many areas where (a) the coastal strip was stable over this time interval, (b) a detailed record is available in short time increments (a few decades: e.g. beach ridges), (c) the sediments are suitable for analysis. One such area is described here.

St. Vincent Island is located near the mouth of the Apalachicola River, Fla., on the coast southwest of Tallahassee. It is a complex beach ridge plain, having some 200 beach ridges. Deposition was spread over roughly 4,000 years, giving (average sense) one ridge per 20 years, with perhaps 400,000 or more laminae (roughly one per week). The materials are clean quartz sand.

There are a dozen or more ridge sets; some stand high, some low. The topographic differences reflect an up-and-down history of sea-level, over the most recent 4,000 years, because they show distinct stable episodes spanning 100 or more years each. This cannot be due to storms.

The variability diagram (Tanner, 1986) permits either a swash zone, or a dune, interpretation. The external geometry and internal details require a swash origin. The tail-of-fines diagram (Tanner, 1986) shows that the oldest

sets (A, B, C and D) are made of sands which had a long river transport history, then only a brief wave-working history, prior to deposition.

The historical sequence of mean parameters, for successive beach ridge sets, shows an evolution of the near-shore sand pool from which the ridges were built (Demirpolat et al, 1986). This historical plot shows long-term improvement in sorting (oldest to youngest; despite excursions), and fluctuations about the mean size.

Relative moment measures were computed to minimize sand pool effects. The plane table profile permits a comparison of changes in relative parameters with changes in vertical position (relative to modern sea-level). The results are clear when relative standard deviation is plotted, sample by sample, against relative kurtosis. Samples known to come from boundaries (vertical changes) plot in the "low relative kurtosis, low relative standard deviation". There are very few exceptions. The changes in sea-level indicated in this study were in the range 0.5 to about 4.0 m (Authors).

072 DICKINSON, R. E. and CICERONE, R. J. 1986. "Future Global Warming From Atmospheric Trace Gases," Nature, Vol 319, pp 109-115.

Human activity this century has increased the concentrations of atmospheric trace gases, which in turn has elevated global surface temperatures by blocking the escape of thermal infrared radiation. Natural climate variations are masking this temperature increase, but further additions of trace gases during the next 65 years could double or even quadruple the present effects, causing the global average temperature to rise by at least 1° C and possibly by more than 5° C. If the rise continues into the twenty-second century, the global average temperature may reach higher values than have occurred in the past 10 million years. (Authors).

073 DIECKMANN, R., PARTENSCKY, H. W., and OSTERTHUN, M. 1987. "The Far-Field Littoral Drift System and Sedimentation in a German Coastal Section," Proceedings of Coastal Sediments '87, Vol 2, pp 1706.

The North Frisian tidal flats in the north of the German Bight are morphologically unstable. A solution to this problem can be achieved by the construction of an offshore dyke and a security dam. As a result of this, an input of about 185 10^6 m^3 of sediment into the Suderau tidal basin has to be expected.

This paper deals with the question of the origin of this sediment. On the basis of the sedimentation processes that have taken place in the Eider estuary since the construction of a barrage, it was possible to analyze the local littoral drift system and to prove that the input of sediments originates from the bottom of the North Sea.

Similar conditions will occur in the Suderau tidal flat area after the construction of the security dam. Changes in the local littoral drift system and the effects of the dam on the general conditions for sedimentation in the Suderau and the adjacent outlying sands will be discussed. (Authors).

074 DILLION, W. P., and OLDALE, R. N. 1978. "Late Quaternary Sea-Level Curve: Re-interpretation Based on Glacio-Tectonic Influence," Geology, Vol 6, pp 56-60.

High-resolution seismic-reflection profiles obtained between Chesapeake Bay and Long Island along 2,500 km of trackline appear to show tilting of a large lithospheric block within the United States eastern continental margin. This warping probably was related to glacial loading and unloading. It has resulted in postglacial changes in depth at locations where radiocarbon-dated samples have been obtained and thus has affected the eustatic sea-level curves deduced from these samples. Corrected values indicate significantly shallower depths in the older (deeper) parts of the United States east coast curve and thus a revised estimate of global sea-level lowering during Wisconsinan time. (Authors).

075 DOMINGUEZ, JOSE M. L., MARTIN, LOUIS, and BITTENCOURT, ABILIO C. S. P. 1987. "Sea-Level History and Quaternary Evolution of River Mouth-Associated Beach Ridge Plains Along the East-Southeast Brazilian Coast: A Summary," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 115-128.

The record of recent sea-level variations for the east-southeast Brazilian coast is characterized by a maximum height of 5 m above present sea-level about 5.1 ka. Sea-level fall from that highstand was interrupted by high-frequency sea-level oscillations as large as 2-3 m acting on time scales of no more than 200-300 years. This sea-level history had a profound effect on the evolution of sedimentary plains associated with the mouths of the major rivers emptying onto the east-southeast coast of Brazil.

During the 5.1 ka highstand these plains were drowned and barrier island-lagoonal systems associated with intralagoonal deltas were the dominant environments of deposition. During the subsequent drop in sea-level, conditions for the genesis and maintenance of barrier island-lagoonal systems were highly unfavorable. The coastline rapidly prograded, giving origin to regressive sand sheets.

In the Jequitinhonha River beach-ridge plain, the short-term Holocene sea-level rises caused drowning of the river mouth and induced abrupt shifts in the lower river course. In the Doce river beach-ridge plain, these same events resulted in the formation of new barrier island-lagoonal systems as well as reoccupation of old lagoons by the sea. The main sources of sediment for the progradation of the coastline were provided by wave-induced longshore drift of sediments made available through reworking of the inner shelf via falls in sea-level.

These data, derived from study of the Brazilian coast, strongly suggest that sea-level history during the Holocene was a dominant factor in controlling styles of sedimentation around the coastlines of the world. (Authors).

076 **DONN, W. L., FARRAND, W. R., and EWING, M.** 1962. "Pleistocene Ice Volumes and Sea-Level Lowering," Journal of Geology, Vol 70, pp 206-214.

Based upon recent investigations of existing and of Pleistocene ice sheets, revised estimates of late Pleistocene ice volumes and resulting sea-level lowering are made. The thickness of Pleistocene ice sheets has been determined by applying the thickness area ratio of existing ice sheets to the revised areas of the past ice sheets. Revised values are given for the Classical Wisconsin (less than 30,000 years B.P.), early Wisconsin (greater than 30,000 years B.P.), and the Illinoian (third) glacial stages which are here considered equivalent to the Weichsel, Warthe, and Saale stages, respectively. The Illinoian is shown to be the stage of maximum glaciation with consequent sea-level decrease about 50 percent greater than that usually given for the Wisconsin (less than 30,000 years B.P.), early Wisconsin. This stand of the sea is well shown by recent submarine exploration. (Authors).

077 **DONOVAN, A. D., BAUM, G. R., BLECHSCHMIDT, G. L., LOUTIT, T. S., PFLUM, C. E., and VAIL, P. R.** 1988. "Sequence Stratigraphic Setting of the Cretaceous-Tertiary Boundary in Central Alabama," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 299-308.

In central Alabama near the town of Braggs, a complete section across the Cretaceous-Tertiary (K-T) boundary is present within the lower portion of the Clayton Formation. The K-T microfauna and microfloral transition occurs within a 2.5 m (8 ft.) section of interbedded sandstones and limestones that directly overlies a sequence boundary, marked by regional truncation of the underlying Prairie Bluff Formation. This sequence boundary is related to a major eustatic fall in the late Maastrichtian (67 Ma). The interbedded sandstones and limestones in the basal Clayton Formation are interpreted as two backstepping marine parasequences deposited on the inner shelf during the subsequent relative rise in sea-level. These two backstepping parasequences are overlain, in turn, by 1.5 m (5 ft) of glauconite-rich strata representing a condensed section produced during a period of slow terrigenous deposition, continued parasequence backstepping, and shoreline retreat.

Three small iridium anomalies have been identified at the Braggs locality. These anomalies occur at marine-flooding surfaces, interpreted to be parasequence boundaries, in the uppermost Prairie Bluff and basal Clayton formations. The uppermost of these anomalies also coincides with the base of the well-developed condensed section in the basal Clayton Formation. The concurrence of iridium concentrations with marine-flooding surfaces at Braggs suggests that iridium was present in the open ocean during the latest Maastrichtian through earliest Danian but concentrated only during periods of terrigenous-sediment starvation. Thus, variations in sediment supply and possibly basin location are critical factors controlling iridium enrichment across the K-T boundary. (Authors).

078 **DOUGLASS, S. L.** 1987. "Coastal Response to Navigation Structures at Murrells Inlet, South Carolina," Technical Report CERC-87-2, US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, MS, 244 pp.

Coastal response to navigation structures at Murrells Inlet, S.C., is documented herein. Data, which result from a postconstruction monitoring program, consist of beach, inlet, and jetty surveys, aerial photography, visual wave observations, wave buoy results, hindcast wave results, and site inspection trips. These data were collected during the period 1978-1982, approximately 5 years after jetty construction began.

Beach change and wave data collected indicate that net longshore sand transport at the inlet has not been strongly to the south as previously assumed. the variability of longshore sand transport rate in time and space appears to be very important to coastal response to the jetties. Longshore transport rates are calculated from visual wave observations for 1979-1982. The direction of net transport was northward at all four wave data locations in 1979 and was toward the inlet from both sides during 1980-1982. The only wave data south of the inlet was close enough to be strongly affected by the jetties; therefore, a local reversal in net transport direction could have occurred south of the inlet during 1980-1982. Analysis of hindcast wave data for 1956-1975 indicates that the major southerly growth of the tip of Garden City in the early 1960's may have been in response to an unusually strong period of southerly sand transport.

Possible modifications to the navigation project are suggested for further consideration and analysis. Improvements in the Murrells Inlet monitoring data collection program are recommended in light of the conclusions reached in this report.

079 **DREYFOOS, W. W., PRAUSE, W. K., and DAVIDSON, M. A.** 1989. "Local Responses to Sea-Level Rise: Charleston, South Carolina," Proceedings of Coastal Zone '89, Vol II, pp 1395.

The authors summarize the local government response to sea-level rise from a planning point of view. Pertinent factors such as infrastructures, land use, and residential and commercial development are considered for future planning needs. (Gorman).

080 **DUBOIS, R. N.** 1975. "Support and Refinement of the Bruun Rule on Beach Erosion," Journal of Geology, Vol 83, pp 651-657.

If a beach and nearshore profile is at equilibrium, as sea-level rises, the Bruun Rule on beach erosion indicates the foreshore profile can be elevated in direct proportion to rising sea-level. This study supports the concept that rising sea-level can cause beach erosion. At Terry Andrae State Park, Wisconsin, which borders Lake Michigan, a field study conducted from spring to fall of 1971 shows that when wave energy was reasonably constant the beach eroded by about 23 ft as lake water level rose by 1 ft. Of the 23 ft about 6 ft was lost solely due to the drowning effect of rising water level. Also, for given wave energy level, the foreshore zone increases in elevation in direct proportion to the increase in the elevation of the water level and

the foreshore zone retreats parallel to itself with rising water level. (Author).

081 DUBOIS, R. W. 1976. "Nearshore Evidence in Support of the Bruun Rule on Shore Erosion," Journal of Geology, Vol 84, pp 485-491.

The Bruun Rule on shore erosion states that for a beach and nearshore profile at equilibrium, as water level rises, sediments are eroded from the beach and deposited in the nearshore zone; in turn, the nearshore bottom is elevated in direct proportion to the rise in water level. The Rule was tested under field conditions. At Terry Andrae State Park, Wisconsin, nearshore profiles in Lake Michigan were surveyed once a week from April through July as lake water level seasonally rose. The nearshore zone consists of two longshore bars which parallel the shore. The Bruun Rule is applicable in the zone of the first longshore bar system. As lake water level rose, the bars advanced landward, and from the base of the foreshore to the crest of the first bar, the elevation of the nearshore bottom increased. On the lakeward slope of the first bar crest, no deposition or erosion occurred. The elevation of the second bar crest remained constant as water level rose. (Author).

082 DUBOIS, R. N. 1980. "Hypothetical Shore Profiles in Response to Rising Water Level," Proceedings of the Per Bruun Symposium, Newport, Rhode Island, International Geographical Union Commission on the Coastal Environment, Bureau for Facility Research, Western Washington University, Bellingham, Washington, pp 13-31.

The purpose of this paper is to present some of my thoughts on how shore profiles should respond to rising water levels. The first part of this paper will focus on the behavior of an equilibrium shore profile in response to a rise in water level; the state of equilibrium will be with respect to wave action and sediment supply. The second part of this paper will deal with the behavior of disequilibrium shore profiles in response to rising water levels; the state of disequilibrium will be with respect to sediment supply and wave action, respectively. Throughout this paper, it is assumed that the physical properties of sediments in each segment of a shore profile remain reasonably constant as the magnitude of coastal processes varies.

The behavior of a shore profile can be conceptualized to range from a state of complete equilibrium to a state of complete disequilibrium with respect to coastal processes. A shore profile adjusts to wave dimensions, sediment supply, and water levels. If the magnitude of each of these primary variables remains constant, then the profile can be viewed as being in a state of complete equilibrium. On the other hand, if the magnitude of all process variables continues to change with the passage of time, then the profile can be viewed as being in a state of complete disequilibrium. A shore profile may also exist in a state between complete equilibrium and complete disequilibrium; for example, a profile may be in equilibrium with one or two of the process variables and in disequilibrium with the rest of the variables.

When a shore profile is in complete equilibrium, the position of the total profile relative to a fixed point on land and the shape of the profile

remain constant. If sediments are lost from a shore zone and the shore profile retreats landward while its shape remains constant, then a parallelogram can be used to qualitatively and quantitatively describe the change that has occurred on the shore (Bruun 1962; Coastal Engineering Research Center 1973, p. 4-122; Dubois 1977). Most of the shore models in this paper are constructed from parallelograms and represent a first approximation of the possible behavior of shore profiles in response to rising water levels. (Author).

083 DUBOIS, R. N. 1982. "Relation Among Wave Conditions Sediment Texture, and Rising Sea-Level: An Opinion," Shore and Beach, Vol 50, pp 30-32.

Most sandy shorelines around the world are eroding, and one cause of this erosion may be attributed to a relative rise of sea-level. For a shore profile at equilibrium with wave and current processes, Bruun postulated that a rise of sea-level can cause sediments to be eroded from the beach and deposited on the shore bottom so that the bottom can be elevated in direct proportion to the rise of water level; the volume of sediments eroded from the beach is equal to the volume of sediments deposited on the shore bottom. Field and laboratory data have been presented in support of Bruun's Rule. In recent years, several writers have used or noted Bruun's Rule in their research.

The purpose of this paper is to suggest how a rise of water level and wave conditions can be linked to cause beach erosion and nearshore deposition, and to suggest that a rise of sea-level may have an influence on the texture of shore sediments. (Introduction).

084 EBERSOLE, B. A. 1982. "Atlantic Coast Water-Level Climate," Wave Information Studies Report 7, US Army Engineer Waterways Experiment Station, Vicksburg, MS, pp 495.

The U. S. Atlantic coast water-level climate, developed for the Wave Information Study (WIS), is comprised of the following products at each of 20 locations along the coast.

a. Trends and variability in mean sea-level.
b. Magnitudes of the expected water-level climate via estimated probability density and cumulative distribution functions for astronomical tide, storm surge, and total water level.
c. Duration statistics for both storm surge and water level.
d. Extremal storm surge information as a result of extratropical storms.

The nature of the water-level data, the analysis procedures used, and the interpretation of the results are included. (Author).

085 EL-ASHRY, M. T. 1971. "Causes of Recent Increased Erosion Along United States Shorelines," Geological Society of America, Bulletin 82, pp 2033-2038.

The presence of beach ridges extending parallel to the present shorelines of many areas along U.S. coast indicates progradation of these areas after the last glacial stage of the Pleistocene epoch. The general trend of shoreline changes in the past 100 years, however, was erosion of several hundred ft of the beaches. Three major causes are considered responsible for such increased erosion. These are: (1) hurricanes and severe storms; (2) recent eustatic rise in sea-level; and (3) interference by man with natural shore processes. (Author).

086 **EMBRY, A. F.** 1988. "Triassic Sea-Level Changes: Evidence From The Canadian Arctic Archipelago," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 249-260.

Triassic sea-level changes are not well documented because of a scarcity of Triassic marine strata over many of the continental interiors and on passive continental margins. An excellent laboratory for studying Triassic sea-level changes is the Sverdrup Basin, which was a major depocenter in the Canadian Arctic Archipelago from the Carboniferous to early Tertiary. Marine Triassic strata are widespread across the basin and are as thick as 4,000 m.

The established stratigraphic pattern for the Triassic succession consists of thick progradational wedges of deltaic and marine strata, alternating with thin, transgressive, clastic units (T-R cycles). On the basin margins, subaerial unconformities cap the progradational wedges, and over much of the basinal area, submarine unconformities form the cycle boundaries. Nine T-R cycles occur in the basin and are interpreted as having been generated by an interplay of eustatic sea-level change, gradually decaying thermal subsidence, and variable rates of sediment supply and load subsidence. In this model, rapid eustatic sea-level rises, coincide with major transgressions that occurred in earliest Griesbachian, earliest Smithian, late Smithian, earliest Anisian, early Ladinian, earliest Carnian, mid-Carnian, earliest Norian, earliest Rhaetian, and earliest Jurassic. Progradation occurred in the intervening time intervals under conditions of slow eustatic sea-level rise, stillstand, and fall.

The long duration of each of the sea-level cycles (about 5 million years) and the apparent lack of Triassic glacial deposits indicate the cycles had a tectono-eustatic origin that relates sea-level changes to changes in the volume of the ocean basins. Sea-level rises are related to episodes of increased rates of seafloor spreading and oceanic volcanism that resulted in reduced oceanic-basin volume. The intervals of sea-level fall occurred when seafloor spreading and associated volcanism were subdued and the ocean basins gradually enlarged due to thermal subsidence. (Authors).

087 **EMERY, K. O., and AUBREY, D. G.** 1986. "Relative Sea-Level Changes From Tide-Gage Records of Eastern Asia Mainland," Marine Geology, Vol 72, pp 33-45.

Records from 22 tide-gage stations along the mainland coast of eastern Asia document low-frequency vertical movements of the land perhaps biased by unevaluated changes of sea-level. The land is rising (relative to sea-level)

as much as 5 mm year^{-1} in the areas of massifs and ancient foldbelts and subsiding as much as 9 mm year^{-1} in areas of Cenozoic basins and foldbelts. Although the tide-gage records are sparse, inferences from them are supported by the stratigraphy and structure of the region, and by raised and submerged sealevel terraces. Thus, relative changes of sea-level are heavily influenced here by tectonic and isostatic as well as eustatic factors, just as in Japan, Scandinavia, and North America where tide-gage records are much more abundant. Higher frequency (2-25-year periods) sea-level fluctuations how broad peaks between 2 and 4 years, and near 10 years. Some of these fluctuations correlate with behavior of the Kuroshio Current, which along with freshwater inflow dominates the hydrography of the eastern Asian continental shelves. Observations of water mass fluctuations are too sparse to identify direct causes of all high-frequency variability. (Authors).

088 EMERY, K. O., AUBREY, D. G., and GOLDSMITH, V. 1988. "Coastal Neotectonics of the Mediterranean from Tide-Gage Records," Marine Geology, Vol 81, pp 41-52.

Records from tide gages in Israel and Egypt supplement the many geological and archeological investigations that have contributed information about relative sea-level changes in the Mediterranean region. Seven such records reveal changes during the past few decades that accord with prior inferences about land movements in this region (emergence along the coast of Israel and at Alexandria and subsidence at the Nile Delta and the head of the Gulf of Suez). Twenty-four other tide-gage records for the rest of the Mediterranean region indicate more uniformity (submergence of land or rise of sea-level) in the west, but with greater movements of the land attributed to probable plate underthrusting in Turkey and Greece, to volcanism near Mount Etna, to deltaic compaction' at Izmir, and to deltaic compaction coupled with water than pumping at the Po Delta. (Authors).

089 EMERY, K. O., and GARRISON, L. E. 1967. "Sea-Levels 7,000 to 20,000 Years Ago," Science, Vol 157, pp 684-687.

Relative sea-levels for early post-Pleistocene time are best known from radiocarbon dates of sediments on the coastal continental shelves off Texas and off northeastern United States. Differences in indicated rates of the rise of relative sea-level and in depths of the shelf-breaks reveal differentiated vertical movement of the two shelves during this time, with the results that the Atlantic shelf has sunk with respect to the Texas shelf. (Authors).

090 EMERY, K. O., WIGLEY, R. L., RUBIN, M. 1965. "A Submerged Peat Deposit Off the Atlantic Coast of the United States," Limnology and Oceanography, Vol 10, Supplement, pp R97-R102.

A sample of salt-marsh peat from a depth of 59 m at the northwestern margin of Georges Bank has a radiocarbon age of 11,000 $\pm$ 350 years. No

greater depth or age of salt-marsh peat lying exposed on the ocean floor elsewhere in the world are known to the authors. The age corresponds well with the date of ice retreat from the Gulf of Maine and with the ages of oyster and other shells that mark the advance of the ocean across the bank and the adjacent Continental Shelf. (Authors).

091 ENFIELD, D. B. and ALLEN, J. S. 1980. "On the Structure and Dynamics of Monthly Mean Sea-Level Anomalies Along the Pacific Coast of North and South America," Journal of Physical Oceanography, Vol 10, pp 557-578.

The behavior and relationship of anomalies of monthly mean sea-level, coastal sea surface temperature and alongshore wind stress for the eastern Pacific Ocean during the period 1950-74 have been studied. Sea-level and temperature records from Yakutat, Alaska (59° N) to Valparaiso. Chile (33° S) and computed alongshore wind stress at near coastal gird points from Yakutat to Matzatlan, Mexico (23° N) have been utilized. The positive and negative sea-level anomalies, corresponding to El Niño-anti El Niño cycles, are well correlated throughout the tropics of both hemispheres and are detectable at the California stations. From Crescent City to Antofagasta. Chile the sea-level anomalies were correlated with the Southern Oscillation Index above the 99% significance level. The maximum station separations for which sea-level anomalies were correlated among themselves above the 99% significance level varied from 6000 km (Yakutat to San Diego) to more than 12 000 km (Prince Rupert to Matarani). A well-defined lagged correlation structure of the sea-level anomalies exists which suggests a poleward propagation of events in the Northern Hemisphere and leads to a phase speed estimate of 180 $\pm$ 100 km day^{-1}. Cross-spectral results imply that the propagation occurs predominantly at subannual frequencies and lead to a lower range of phase speeds (60-100 km day^{-1}). These estimates are consistent with theory and observations concerning wave propagation processes but are too fast to be explained by large-scale adjective processes. The correlations of sea-level anomalies with anomalies of the local alongshore wind stress are greatest from Sitka to Crescent City; they decrease south of Crescent City, with a marginal value at San Francisco, the relation between the alongshore sea-level slope and the alongshore component of the wind stress is consistent with a mass balance between a geostrophic onshore-offshore velocity below the surface layer and an onshore--offshore Ekman transport. (Authors).

092 ENVIRONMENTAL PROTECTION AGENCY. 1986. Effects of Changes in Stratospheric Ocean and Global Climate, Washington, DC, USA, Vol 1-4.

This report examines the possible consequences of projected changes in stratospheric ozone and global climate resulting from emissions of chlorofluorocarbons, carbon dioxide, methane, and other gases released by human activities. During the week of June 16-20, the United Nations Environment Program and the U.S. Environmental Protection Agency sponsored an International Conference on the Health and Environmental Effects of Ozone Modification and climatic change, which was attended by scientists and

officials from approximately twenty countries from all areas of the world. The four volumes of this report comprise the proceedings of that conference.

Volume 1 provides an overview of the issues as well as the introductory remarks and reactions from top officials of the United Nations Environment Program and the United States Environmental Protection Agency, two U.S. Senators, and representatives from industry, academia, and environmental groups. Volumes 2, 3, and 4 provide more detailed investigations on the effects of ozone depletion, climate change, and the rise in sea-level that might result from a global warming. (Modified Preface).

093 ETKINS, R., and EPSTEIN, E. S. 1982. "The Rise of Global Mean Sea-Level as an Indication of Climate Change," Science, Vol 215, No. 4530, pp 287-289.

Rising mean sea-level, it is proposed, is a significant indicator of global climate change. The principal factors that can have contributed to the observed increases of global mean sea-level in recent decades are thermal expansion of the oceans and the discharge of polar ice sheets. Calculations indicate that thermal expansion cannot be the sole factor responsible for the observed rise in sea-level over the last 40 years; significant discharges of polar ice must also be occurring. Global warming, due in some degree presumably to increasing atmospheric carbon dioxide, has been opposed by the extraction of heat necessary to melt the discharged ice. During the past 40 years more than 50,000 cubic kilometer of ice has been discharged and has melted, reducing the surface warming that might otherwise have occurred by as much as a factor of 2. The transfer of mass from the polar regions to a thin spherical shell covering all the oceans should have increased the earth's moment of inertia and correspondingly reduced the speed of rotation by about 1.5 parts in 10^8. This accounts for about three quarters of the observed fractional reduction in the earth's angular velocity since 1940. Monitoring of global mean sea-level, ocean surface temperatures, and the earth's speed of rotation should be complemented by monitoring of the polar ice sheets, as is now possible by satellite altimetry. All parts of the puzzle need to be examined in order that a consistent picture emerge. (Authors).

094 EVANS, D. L. 1985. "Vertical Structure of the Brazil Current," Nature, Vol 315, pp 48-50.

Recent interest in world climate and interaction of the ocean and atmosphere have led to studies of the meridional fluxes of fresh water and heat in the ocean. Several such studies have noted the asymmetry of heat fluxes between the North and South Atlantic oceans. In particular, the fluxes across both 24° N and 24° S appear to be northward. Crucial to all of the direct calculation techniques is an accurate estimate of the transport of the western boundary currents. In the North Atlantic, useful measurements in the Florida Current over a long period of time are available. For the much less studied South Atlantic, no comparable time series has been made. The direct measurements of Brazil Current velocities near 23° S reported here show southward

flow of warm water above 400 m depth and northward flow of Antarctic Intermediate Water below that. The upper layer transport was ~6 x 10^6 m^3s^{-1} towards the south offshore of the 200 m isobath, with an indication of comparable flow on the shelf. (Author).

095 **EVERTS, C. H.**, 1987. "Continental Shelf Evolution in Response to a Rise in Sea-Level," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 49-58.

As the shoreface part of the inner continental shelf retreats, its trailing edge forms a new surface which becomes an extension of the ramp. Waves are primarily responsible for shaping the concave shoreface at the shallow, most landward part of the shelf. Shoreface retreat occurs because of sand losses and/or sea-level rise. The ramp, located seaward of the shoreface, is usually a planar feature with a seaward inclination. Its slope, γ, at the time it is formed is dependent upon the long-term average retreat rate of the shoreface, $\bar{s}$, and the long-term average rate of sea-level rise relative to the shoreface, $\bar{a}$. The shoreface and ramp usually join asymptotically between 1 and 5 km from shore. Retreat of the shoreface may occur without a significant change in shape. Shoreline retreat on the order of kilometers is almost always the response of the shoreface to a long-term rise in sea-level.

Recent shoreline retreat rates measured over a short time period (10^1 to 10^2 years) can be compared to long-term average past rates (10^3 to 10^4 years) to forecast shoreline behavior in the future, unless sedimentation or tectonism altered the ramp slope formed in the past. The recent shore retreat rate, s_p, for a given recent sea-level rise rate, a_p, is compared to the present average slope of the ramp, γ_p, where γ_p is assumed equal to $\bar{a}/\bar{s} = \gamma$. If $\gamma_p >> a_p/s_p$, the present shore retreat rate is probably anomalously large compared to the long-term average rate for the reach of coast being considered. If $\gamma_p << a_p/s_p$, the present shore retreat rate is probably anomalously small compared to the long-term average rate for that reach. The future shore retreat rate, s_f, can consequently be expected to increase rather than decrease in a trend more consistent with $s_f = a_f/\gamma_p$. When the reason for present anomalous rates is established, a more definitive projection of the future rate can be made.

A test of the relationship of γ_p to a_p/s_p was made at five barrier island sites along the mid-Atlantic coast of the United States. At Smith and Assawoman Islands in Virginia, present shoreline retreat rates are similar to the long-term shoreline retreat rates of the past when referenced to the same relative sea-level rise rates. These islands are migrating landward (i.e., both ocean and lagoon shorelines are moving away from the ocean at about the same rate) as littoral sand is transported landward by overwash and tidal inlet processes. At Ocean City, Maryland; Sandbridge, Virginia, and a portion of the Outer Banks, North Carolina, the present shore retreat rate is anomalously low when compared to the present relative rate of sea-level rise. These islands are narrowing (i.e., ocean and lagoon shorelines are moving toward each other). When the islands reach a critical width (perhaps 350 m),

island migration will begin and the ocean shore retreat rate will likely increase of five to eight times the present rate. (Author).

096 **EVERTS, C. H.** 1985. "Sea-Level Rise Effects on Shoreline Position," Journal of Waterway, Port, Coastal and Ocean Engineering, Vol 111, No. 6, pp 985-999.

Using a conservation of sand approach, the effects of a rising sea surface are quantified and separated from other causes of shore retreat. Site--specific data important in predicting shoreline changes are: (1) Initial shoreface and backbeach profile; (2) subsequent backbeach profile; (3) relative sea-level rise; (4) grain size distribution of sediment landward of the shoreface; and (5) net quantity of sand-sized material that enters or leaves a specified coastal reach. A key element of the approach, Bruun's assumption of a shoreface is dynamic equilibrium with the sea surface, was evaluated and found to be reasonably accurate. Field application of the method shows that sea-level rise accounts for about 53% of the total shore retreat of 5.5 m/year measured at Smith Island, Virginia, and for about 88% of the measured, 1.7-m/year retreat of the barrier island south of Oregon Inlet, North Carolina. Net sand losses account for the remainder. Because shoreface adjustments are required to maintain an equilibrium profile, sand replenishment is probably the most realistic method to stabilize a shore against the effects of relative sea-level rise. Conversely, a negative sediment budget may also be mitigated by structures which hinder the movement of sand away from a problem beach and enhance its deposition there. (Author).

097 **FAIRBRIDGE, R. W.** 1961. "Eustatic Changes in Sea-Level," pp 99-185, in Ahrens, L. H., and others, Editors, Physics and Chemistry of the Earth, Vol 4, New York, Pergamon Press, Inc., pp 317.

This classical paper addresses the causes of eustatic changes of sea-level. Fairbridge discusses historical observations of sea-level, theories of shore displacement, Quaternary sea-level, and sea-level oscillations in light of climatic events. (Gorman).

098 **FAIRBRIDGE, R. W.** 1974. "The Holocene Sea-Level Record in South Florida," in Gleason, P. J. (ED.) Environments of South Florida: Past and Present, Miami Geological Society, Memoirs 2, pp 223-232.

The generally accepted concept of a gradual Holocene sea-level rise continuing up to the present in Florida is inconsistent with world data. The eustatic rise reached its present height 6,000 years ago, and since then has been oscillating. Four main transgressions and regressions are proposed leading to major changes in the geography of coastal Florida and the Everglades. No detailed geological surveys have been carried out, so that only a very tentative model can be offered. The rate of crustal subsidence in South Florida has not been systematically measured. (Author).

099 FAIRBRIDGE, R. W. 1981. "Holocene Sea-Level Oscillations," Striae, Vol 14, pp 131-141.

A brief history of the Holocene eustatic sea-level concept recognizes the important role of the Florins in helping to furnish the first chronological basis for global correlations. The mechanisms of tropical limestone erosion and biological deposition bring precise height indications of sea-level oscillations in non-glacial regions. The mechanisms of beach formation and preservation, together with their distribution in high-latitude glacio-isostatic uplift regions, disclose evidence of multiple energy pulses that are superimposed upon eustatic, isostatic and geodial trends. An hypothesis is suggested, that postulates global climatic patterns which appear to have geomagnetic and extra-terrestrial controls. (Authors).

100 FAIRBRIDGE, R. W. and KREBS, O. A.. JR. 1962. "Sea-Level and the Southern Oscillation," Geophysical Journal of the Royal Astronomical Society, Vol 6, No. 4, pp 532-545.

An average curve for the world annual mean sea-level for the century 1860-1960 has been obtained from a carefully selected world series of tide gage records. We have eliminated data from tectonically unstable areas and other obviously anomalous records. Five-year running means provide us with a residual curve that may approach a eustatic standard (probably glacioeustatic). The lowest point of sea-level was about 1890; the mean rise from 1900-1950 was 1.2 mm annually, but the fastest decade was 1946-1956 with 5.5 mm. The pattern varies somewhat if plotted ocean by ocean.

The non-smoothed, annual curve shows a 2-3 year cyclicity of 10-30 mm amplitude. For the world curve this periodicity resembles the 2-3 year atmospheric pressure cycle known as the "Southern Oscillation", being in phase with the S.E. Pacific node. The reciprocal, Indian Ocean node is well reflected in the Indian Ocean, and periodically, dominates over the Pacific pattern in the Atlantic Ocean.

When the effect of a pressure anomaly of 1 mb is taken as equivalent to 10 mm departure of sea-level, it is found that is still a large residual generally in the same phase. It would seem that steric effects and associated wind systems are mainly responsible. (Summary).

101 FAIRBRIDGE, R. W., and NEWMAN, W. S. 1968. "Postglacial Crustal Subsidence of the New York Area," Zeitchrift fuer Geomorphologie, Neue Folge 12, No. 3, pp 296-317.

This report is an outcome of investigations concerning recent shore-line changes and the late-Quaternary geology of the north shore of Long Island and the adjacent waters of Long Island Sound (Figure 1). There is little reason to doubt that this is a shore-line of submergence. But is it possible to distinguish whether submergence has resulted from crustal subsidence or from

eustatic rise of sea-level? Evidence suggests that crustal subsidence is affecting the area of New York City and southern New England at the present time and has been continuing since the mid-Holocene. Tide gage studies and precise leveling surveys confirm contemporary subsidence, while varied data from the fields of archeology, physiography, stratigraphy, paleontology, paleobotany, and radio-chronology extend the record back several thousand years. (Introduction).

102 **FINKELSTEIN, K., and FERLAND, M. A.** 1987. "Back-Barrier Response to Sea-Level Rise, Eastern Shore of Virginia," Nummedal, D., Pilkey, O.H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 145-156.

The barrier and back-barrier environments of Virginia were examined to determine the effects of sea-level change on the resulting stratigraphy. Relative sea-level rise and/or a local sediment deficit have caused the retreat of these barrier islands during the Holocene. The results, reflected by the stratigraphy, are a narrowing of the back-barrier region, a decrease in the tidal prism with a probable constriction of inlets, and an increase in the infilling of marshes and tidal flats associated with calmer water conditions. Core data show the progressive fine-grained infilling of the back-barrier system. As infilling proceeds, the general back-barrier environment passes from a higher energy lagoon to a lower energy salt marsh and tidal flats. The sedimentary pattern depicts a fining-upward "regressive" stratigraphy behind the receding barriers. (Authors).

103 **FISHER, J. J.** 1980a. "Holocene Sea-Level Rise, Shoreline Erosion and the Bruun Rule - Overview," Proceedings of the Per Bruun Symposium, Newport, Rhode Island, International Geographical Union Commission on the Coastal Environment, Bureau for Facility Research, Western Washington University, Bellingham, Washington, pp 1-5.

These papers on the application of the Bruun Rule to shoreline erosion were part of a symposium that the author conducted as conference chairman as part of the Atlantic Regional Conference of the International Commission of the Coastal Environment at Newport, Rhode Island, in the fall of 1979. As background information, briefly, the Bruun Rule postulates that erosion of the shoreline is necessary on a rising sea-level to maintain a profile of equilibrium if there is sediment supply deficit. At the 23rd International Geographic Union's Congress in Moscow, U.S.S.R., in the summer of 1976, which the author attended, application of this concept was suggested, in part, as an explanation of some shoreline erosion. The author reported on the symposium in Geotimes (Fisher 1977a). The following summer, 1977, at the 10th International Quaternary Association's Congress in Birmingham, England, at the session on Quaternary shorelines, the author presented (Fisher 1977b) information on this concept as applied to the Rhode Island and North Carolina coasts of the U.S.A. as it was affected by the Holocene rising sea-level. (Author).

104 **FISHER, J. J.** 1980b. "Shoreline Erosion, Rhode Island and North Carolina Coasts - Test of Bruun Rule," Proceeding of the Per Bruun Symposium, Newport, Rhode Island, International Geographical Union Commission on the Coastal Environment, Bureau for Facility Research, Western Washington University, Bellingham, Washington, pp 32-54.

Analysis of Rhode Island shoreline retreat, measured on aerial photographs from 1939 to 1975 together with sea-level rise rates allows a test of the Bruun Rule. This rule suggests that as sea-level rises, sediment eroded from the shore is deposited offshore equal to this sea-level rise. Submergence by a sea-level rise of 0.3 cm/year accounts for only 15% of the average shoreline retreat of 0.2 m/year. Overwash accounts for 26%, while inlet deposition accounts for 35% of this retreat. The remaining 24% of the eroded sediment is deposited offshore between the breaker zone and wave base limit. A similar sedimentation situation exists along the higher energy North Carolina coast with erosion averaging 2.0 m/year. These are the first studies of the Bruun Rule on barrier island coastlines. (Author).

105 **FLICK, R. E., and CAYAN, D. R.** 1984. "Extreme Sea-Levels on the Coast of California," Proceedings of the 19th Coastal Engineering Conference, American Society of Civil Engineers, Houston Texas, pp 886-898.

During the winter of 1982-1983, a combination of high tides, higher than normal sea-level and storm-induced waves were devastating to the coast of California. Damage estimates for public and private property destruction in the coastal counties of California total over $100,000,000. Much higher than average sea-levels played a very important contributory role in the flooding damage. This paper describes and examines the oceanographic and meteorological conditions prevailing during winter 1982-1983, and attempts to put them into perspective using historical information at San Diego. Emphasis is placed on the processes and forces that contribute to extreme sea-levels in the hope that better understanding of these and more complete information on historical extremes will help the engineer in design and in assessment of risk.

The unusually high sea-levels were due to a combination of higher than normal mixed layer temperature associated with a strong, 2-year El Niño, storm surge due to low atmospheric pressure and persistent onshore winds, and cumulative effect of steady, "global" rise in relative sea-level. Higher than average high tides coincided to an unusual extent with the peak sea-levels reached during the numerous storms between November 1982 and March 1983. Important cyclical variations occur in California's tide regime and the consequences of these on extreme tides have not been considered previously. (Authors).

106 **GABLE, F.** 1989. "Contemporary Climate Change and Its Related Effects on Global Shorelines," American Society of Civil Engineers, Proceedings of Coastal Zone '89, Vol 2, pp 1370.

With a possibly large amount of sea-level rise resulting from projectee greenhouse-related climatic warming, many coastal areas of the world may suffer increasing adverse effects. This paper identifies some of these areas, tropical Africa, Pacific Islands, and Republic of Maldives, reportedly experiencing erosion, perhaps due to a local rise in sea-level. (Modified Introduction).

107 **GALVIN, C.** 1983. "Sea-Level Rise and Shoreline Recession," Proceedings of the Third Symposium on Coastal and Ocean Management, American Society of Civil Engineers, pp 2684-2705.

The theory of shoreline displacement due to sea-level change predicts that shoreline displacement equals the flatness of the slope multiplied by the sea-level change. This prediction is tested against three pairs of localities on the U.S. mid-Atlantic coast where the rate of sea-level rise is more than three times the global average. The width of the back bays is used as a measure of slope flatness. In all three test cases, the relative magnitude of shore erosion is opposite that which is predicted by the theory. In fact, in two of the three cases, the localities where theory predicts greater erosion actually show accretion. Analysis of the flux of sediment eroded by sea-level change under mid-Atlantic conditions indicates that it is less than half of one percent of the typical flux due to average longshore transport. The author concluded that sea-level change has negligible effect on shore erosion, compared to fluctuations in longshore transport rate. (Modified Abstract).

108 **GARRETT, C., and TOULANY, B.** 1982. "Sea-Level Variability Due to Meteorological Forcing in the Northeast Gulf of St. Lawrence," Journal of Geophysical Research, Vol 87, No. C3, pp 1968-1978.

In an attempt to understand the causes of low frequency flow through the Strait of Belle Isle, we relate sea-level data from four stations in the northeast Gulf of St. Lawrence to meteorological forcing. Our main tool is a multiple regression, at each frequency, of sea-level on local atmospheric pressure and two orthogonal large scale pressure gradients which represent geostrophic winds. The results show an inverted barometer response to atmospheric pressure and a frequency-dependent response to wind which can be tentatively interpreted in terms of coastal setup due to wind driven longshore currents, or barotropic setup of semi-enclosed regions (such as the northeast Gulf or the whole Gulf). A simple model for barotropic flow through the Strait is developed in order to provide an estimate, from data at the western end of the Strait, of sea-level changes on the Labrador shelf. (Authors).

109 GIBBS, M. J., KENNEY, M., and MARTIN, C. E. 1983. "Economic Impacts of Sea-Level Rise," Proceedings of Coastal Zone '83, Vol III, pp 2754-2767.

This paper reports preliminary results of an ongoing investigation of the potential economic impacts of rising sea-level. Methods for estimating economic impacts and the value of having improved estimates of potential sea-level rise are summarized. Preliminary estimates are reported for the Galveston, Texas study area which indicate that the impacts of sea-level rise may be considerable. Under the high scenario, mean sea level is anticipated to rise by about 2.2 ft (66 cm) by 2025 and 7.75 ft (240 cm) by 2075. This rate of rise is about 1.75 ft (52 cm) and 6.75 ft (210 cm) greater than the historical trend rate of rise expected for 2025 and 2075, respectively. (Modified Abstract).

110 GIESE, G. S., AUBREY, D. G., and ZEEB, P. 1987. "Passive Retreat of Massachusetts Coastal Upland Due to Relative Sea-Level Rise," Massachusetts Coastal Submergence Program, Report No. 300-5-87-815491, Massachusetts Coastal Zone Management, Boston, Massachusetts.

This study was designed to quantify the passive retreat of upland within the coastal communities of Massachusetts due to relative sea-level rise. The losses that presently occur annually, and those that will occur by the year 2025 given three specified projections of future relative sea-level rise, are presented for each community. Also presented are data that provide the means for predicting the rates and cumulative amounts of land area losses due to passive retreat that these communities will suffer in the future given any specified future relative sea-level rise or tidal range change scenario. Finally, color-coded maps are presented for the harbors of Hyannis, Westport and Gloucester that display the areas that would be lost by the year 2100 given any one of four different sea-level rise scenarios. An appendix contains tables, graphs and figures that present the results of the study. A detailed description of the data analysis methodology also is included in the appendix. (Modified Introduction).

111 GIRESSE, P., MALOUNGUILA-N'GANGA, D., BARUSSEAU, J-P. 1986. "Submarine Evidence of the Successive Shorefaces of the Holocene Transgression Off Southern Gabon and Congo," Journal of Coastal Research, Special Issue No. 1, pp 61-71.

At the beginning of the Holocene, the inner parts of the Congo shelf were covered by clear and relatively warm waters. A fauna and microfauna with a reefal tendency had developed in this environment (12,000 BP) resulting in deposits with the highest carbonate content of the shelf. The Holocene transgression has allowed the filling of morphostructural depressions of the inner shelf; the sedimentation rate was very fast (2 to 3 m/1,000 years) when the sea-level reached the site, then was moderated (7 to 30 m/1,000 years) by the end of the transgression.

Dating of mangrove peats allows us to show several successive phases of the Holocene transgression: hesitation before 12,000 BP, a rapid increase

between 11,000 and 5,000 BP, then slowing down toward 5,000 BP. A delay of 1,000 to 2,000 years of this transgression compared with that of the nearby west-African margin is attributed to an oscillation of the oceanic geoid surface. (Authors).

112 **GONZALES, M. A., WEILER, N. E., and GUIDA, N. G.** 1986. "Late Pleistocene Transgressive Deposits from 33° S.L. to 40° S.L., Argentina Republic," Journal of Coastal Research, Special Issue No. 1, pp 39-46.

A synthesis of results for Late Pleistocene paleoeustatism between 33°10′ and 40°00′ S.L. in several areas of the Argentina Republic is presented. Evidence of two transgressive episodes of Late Pleistocene ages was found. The oldest episode is tentatively correlated with the Sangamon Interglacial, whereas the youngest, with C^{14} dates ranging between 38,500±3,000 BP and 25,700±560 BP, is tentatively assigned to a late Interstadial during the Wisconsinan ("Mid-Wisconsinan Interstadial"). For both transgressive episodes, the evidence indicates a palaeosea-level slightly higher than present. (Authors).

113 **GORNITZ, V., and KANCIRUK, P.** 1989. "Assessment of Global Coastal Hazards From Sea-Level Rise," Proceedings of Coastal Zone '89, Vol 2, pp 1345.

A global coastal hazards data base that contains topographic, geologic, geomorphic, erosional and subsidence information is being developed in order to predict the coastal segments at greatest risk to a rise in sea-level caused by future climate warming. High risk areas are characterized by low coastal relief, an erodible substrate, past and present evidence of subsidence, extensive shoreline retreat and high wave/tide energies. Data have been assembled for the U.S.A. and are being extended to the rest of North America. Summaries are presented for coastal relief, lithologic types and landforms, relative sea level changes, tide ranges, and wave heights. Several high risk areas have been tentatively identified and include the central Gulf Coast, South Florida, the North Carolina Outer Banks, southern Delmarva peninsula, and the San Francisco Bay area. (Modified Abstract).

114 **GORNITZ, V., and LEBEDEFF, S.** 1987. "Global Sea-Level Changes During the Past Century," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 3-16.

An updated and expanded data base of tide-gage measurements and late Holocene sea-level indicators is used to obtain a revised global average sea-level rise, corrected for long-range glacio-isostatic and/or tectonic trends. The global average is determined using two methods: (1) the arithmetic mean of all stations, and (2) a new technique which weights contributing stations by distance from a given cell and relative coastal area. A least-squares regression line is then fitted to the composite regional sea-level curve. In

the second method, the global average is derived by averaging 11 regional sea-level curves, weighing each region equally, and also according to the relative reliability of the regional data. This latter step is designed to reduce the influence of regions with few stations or poor data.

The "corrected" average eustatic sea-level rise for both methods is 1.2 $\pm$ 0.3 and 1.0 $\pm$ 0.1 mm/year, respectively. Weighing for regional reliability does not alter the global average significantly. The results agree with those of previous studies and provide an independent verification for a global increase in sea-level during the past century. The closeness in values between the two averaging methods used here and those of earlier studies suggests that the observed change represents a true eustatic sea-level rise in spite of noisy data, geographic bias, and differences in approach and techniques.

Sea-level, corrected for long-term movements, is found to be rising in all but three regions, which have small station populations, sparse long-range data or are tectonically active. Along the east coast of North America, an apparent maximum sea-level rise is observed in both tide-gage and late Holocene sea-level indicators between Chesapeake Bay and New Jersey (36° -40° N). This enhanced mid-Atlantic subsidence, possible indicating neotectonic activity or sediment loading, has persisted for at least the last 7,000 years. Subsidence of northern New England-Maritime Canada (44°-46° N) may be caused by a migrating crest of the peripheral forebulge at the edge of formerly glaciated areas. Sea-level changes in western North America show greater spatial variations than for the east coast, which can be related to more active tectonism in California and British Columbia and to strong, localized isostatic rebound in Alaska.

Most of the recent sea-level rise can be accounted for in terms of the thermal expansion of the upper layers of the ocean and by melting of alpine glaciers. (Authors).

115 GORNITZ, V., LEBEDEFF, S., and HANSEN, J. 1982. "Global Sea-Level Trend in the Past Century," Science, Vol 215, pp 1611-1614.

Data derived from tide-gaging stations throughout the world indicate that the mean sea-level rose by about 12 centimeters in the past century. The sea-level change has a high correlation with the trend of global surface air temperature. A large part of the sea-level rise can be accounted for in terms of the thermal expansion of the upper layers of the ocean. The results also represent weak indirect evidence for a net melting of the continental ice sheets. (Authors).

116 GOY, J. L., and ZAZO, C. 1988. Palaeogeography, Palaeoclimatology, Palaeoecology, Vol 68, No. 2-4, pp 301-310.

Detailed mapping of the coastal areas of the Basin of Elche revealed complex successions of marine Quaternary terraces attached to the tectonically generated, positive reliefs of Santa Pola, Los Arenales del Sol and La Marina. Structural data and lateral facies relationships suggest active tectonics in this area since early Pleistocene times, with E-W trending anticlinal folding

and N-S normal faulting. In this way, staircased marine terraces were generated following the gentle, progressive, uplifting of these reliefs. (Authors)

117 GOY, J. L., and ZAZO, C. 1986. "Western Almeria (Spain) Coastline Changes Since the Last Interglacial," Journal of Coastal Research, Special Issue No. 1, pp 89-93.

We have identified four marine terraces which contain S. bubonius (Tyearrhenian) on the coast of Almeria in southeastern Spain where all marine terraces are affected by normal and strike-slip faulting, manifesting tectonic activity throughout the Quaternary. Two areas were studied for this paper. The following sequence of processes were found in the Adra region: the Tyearrhenian transgression; the Wurm regression with development of alluvial fans; the Holocene transgression and its related eolian deposits; the formation of the Adra delta in the Eighteenth Century as a result of human activity; and the formation of the present Adra delta (19th Century), its progradation, and the formation of spit bars creating lagoons. In the Guardias Viejas-Roquetas coastal area, the following sequence took place: northward tilting of the Camp de Dalias at the beginning of the middle Pleistocene; the formation of three raised stairstepped beaches with S. bubonius. The most recent has been dated at about 104,000±6,000 years (Th/U) or 109,000±16,00012,000 years (Pa/U); the Wurm regression with several oscillations, one of which was very near the present sea-level; the Holocene transgression, with a somewhat higher sea-level than that of today, as evidenced by an Ostrea beach; and the formation of four beach ridge systems, the third of which began to form at about 1,870±35 BP(C^{14}). (Authors).

118 GRANT, D. R. 1985. "Coral Reefs and Sea-Levels," Episodes, Vol 8, No. 3, pp 193-194.

This article is a conference report on coral reefs and sea-levels. The conference was held in Tahiti, 27 May-9 June 1985 and sponsored by International Association of Biological Oceanography. The meeting consisted of 2 days of paper sessions and a field trip to reef, atoll, and volcanic island settings. (Gorman).

119 GREENLEE, S. M., and MOORE, T. C. 1988. "Recognition and Interpretation of Depositional Sequences and Calculation of Sea-level Changes from Stratigraphic Data-Offshore New Jersey and Alabama Tertiary," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 329-356.

Tertiary depositional sequences beneath the continental shelf and slope off New Jersey and Alabama have been studied using seismic-reflection data that have been tied to available wells. These data illustrate second- (10-20 Ma) and third-order (1-5 Ma) depositional sequences in areas close to and distal to progradational siliciclastic depocenters. Paleogene deposition is characterized by sediment-starved deep-water conditions. Second-order sequence boundaries divide these sediments and are recognized by local erosion of underlying strata and deep-marine onlap. Closer to the depocenter, third-order sequences are noted by basinward shifts in coastal onlap, local erosional incision of shelf and slope strata, and planar erosion of basinal sediments. The stacking pattern of third-order depositional sequences modeled using a sinusoidally varying sea-level curve. Upper Oligocene to uppermost middle Miocene third-order sequences are interpreted to compose a second-order supersequence. Neogene strata in these areas are further analyzed to estimate sea-levels. Subsidence is isolated using geohistory analysis and by calculating the average angular-tilt rate of the continental margin. During the early Tertiary, the subsidence rate was slow in both areas. An increase in subsidence rate in the offshore Alabama area during the Neogene is attributed to loading of the lithosphere adjacent to the study area. Short-term falls in sea-level are estimated by measuring the vertical shift in onlapping paralic strata from highstand to lowstand position. Results show a lower overall Neogene sea-level position than the position represented on the Exxon curve but similar magnitudes of short-term fall. (Authors).

120 GRINDROD, J., and RHODES, E. G. 1984. "Holocene Sea-Level History of a Tropical Estuary," Missionary Bay, North Queensland, In Thom, B. G., ed., <u>Coastal Geomorphology in Australia</u>, pp 151-178.

Earlier reconstructions of the course of the Postglacial Marine Transgression (P.M.T.) in eastern Australia are based on either meager observations or summaries of observations from widely spaced sites (see Hopley, 1983). Thom and Roy (1983) construct a transgressional sea-level history for south-eastern Australia based on a synthesis of data from a spread of sites from southern Queensland to Tasmania. The data include revised radiocarbon dates formerly reviewed by Thom and Chappell (1975). Radiocarbon determinations on a range of sea-level-related features are employed. An 'approximate zone of sea-level' for the period 12,000 to 6000 radiocarbon years B.P. is fitted to the data; the upper and lower limits of this area are defined by freshwater facies and shallow water marine/estuarine facies, respectively. Belperio (1979) provides a Holocene sea-level curve for the Townsville area in north-eastern Queensland based entirely on radiocarbon dating of inferred mangrove deposits, including 5 observations from 3 separate sites for samples collected from transgressive deposits. Although both studies provide valuable information regarding transgressive sea-levels in eastern Australia, their application is limited for two main reason. Firstly, in the former study the nature of the relationship between palaeo-sea-level and many of the samples dated is imprecisely known (Thom and Chappell, 1975, p. 91). Secondly, as neither study relies on data from a single location, precision in sea-level reconstruction is potentially limited by between-site variations in the relative heights of land and sea due to tectonic and/or isostatic adjustments in the earths crust, and perhaps by differential rates of sediment compaction.

Clearly the need exists for detailed, site-specific studies of the trace of the P.M.T. in eastern Australia. Mangroves and related vegetational environments provide potentially useful depositional facies for this purpose as they bear a definable relationship to mean tide level. They are also likely to contain fossil material which is distinctive and suitable for radiocarbon dating. Facies samples collected by drilling and shown by palynological techniques to be of intertidal origin provide the basis for the reconstruction of Holocene transgressive sea-level at Missionary Bay. (Authors).

121 **GROVES, G. W., and HANNAN, E. J.** 1968. "Time Series Regression of Sea-Level Weather," Review of Geophysics, Vol 6, No. 2, pp 129-174.

Analysis of sea-level and weather records by frequency is done by the usual methods of spectrum analysis, whereupon a regression analysis is performed in each frequency band. The very complete array of existing statistical procedures, for testing hypotheses and allocating confidence intervals, is then available, suitably modified to take account of the fact that the regression coefficients are complex numbers. Associated statistics, such as partial and multiple coherences and residual spectral matrices, may be treated similarly. The combination of estimates from neighboring frequency bands is also discussed.

These methods are used to study records of sea-level, surface atmospheric pressure, and wind components at Kwajalein and Eniwetok in the Marshall Islands. An 8 x 8 spectral matrix of these variables covering the frequency range of 0 to 0.85 cycles per day is the starting point for the study. The spectra are characteristic of other sea-level and weather spectra at islands in low latitudes. There is good coherence between the two islands, especially in sea-level and atmospheric pressure. At each island there is the usual strong coherence between sea-level and pressure, with moderate coherence between sea-level and wind at each island. Several regression models of sea-level on the weather records are considered in order to study oceanic influences on the sea-level records free from local weather noise. However, the spatial coherence of the residual sea-level is less than that of the original sea-level records, apparently because most of the original spatial coherence results from coherent weather patterns and not from coherent water motions. If the computed statistical relations are taken as the true relations, the results are not compatible with a simplified theory of free planetary barotropic waves on the surface of an ocean of constant depth. Because of statistical uncertainty, however, little can be deduced regarding the presence or absence of planetary waves. (Authors).

122 **GUIDISH, T. M., LERCHE, I., KENDALL, C. G. ST. C., and O'BRIEN, J. J.** 1984. "Relationship Between Eustatic Sea-Level Changes and Basement Subsidence," American Association of Petroleum Geologists, Bulletin 68, No. 2, pp 164-177.

Geohistory reconstructions based on well data provide a direct and quantitative method of estimating basement subsidence. Geohistories, in addition to responding to rates of sediment accumulation and to local and regional subsidence mechanisms, also reflect eustatic sea-level changes. We have

determined quantitatively that component of subsidence that is common to a worldwide set of wells. After compensating for the response of the crust to sedimentation, we find some correlations between the global rate of subsidence and low-frequency changes in the height of eustatic sea-level as determined from the stratigraphic interpretation of seismic data. These results suggests that basement subsidence data, which are independent of the techniques used previously, may be used to recognize variations in eustatic sea-level. However, we are unable to determine the size of the eustatic sea-level excursions because of difficulties in determining and separating variations in lithospheric rigidity, thermal subsidence, and sediment supply independent of tectonic subsidence and sea-level curves, thus avoiding the application of geologic models involving crustal properties we cannot quantify. Geohistory analysis is also a powerful means of studying subsidence on a regional tectonic history. We illustrate this point by subsidence maps through time for the North Sea. (Authors).

123 GUILCHER, A. 1969. "Pleistocene and Holocene Sea-Level Changes," Earth-Science Review, Vol 5, pp 69-97.

The classic glacio-eustatic theory, as it was conceived by Deperet and his supporters, is briefly presented, and the objections against it are discussed. Bourcarl, continental flexure is mentioned. More recent considerations concerning uplifts interfering with variations in sea-level, and resulting possibly from erosional discharge, were developed by Gigout and by Battistini. But these new theories do not imply that the glacio-eustatism is out of date: its principle remains valid. Recent methods allow more accuracy in dating former sea-levels: the ^{14}C method, and the $^{230}Th/^{234}U$ method. Two interglacial high sea-levels are especially noteworthy: they resulted in the Holsteinian and Eemian shorelines which now stand above present-time sea-level in areas where no subsidence occurred. The Eemian (Normannian, Ouljian, etc.) shoreline has left widespread remnants throughout the world, particularly in western Europe and around the Mediterranean, but also in many oceanic islands. The writer criticizes the British conception, which relates the raised beaches belonging to this series to the last interglacial but, one, not to the last one as commonly accepted. The low Quaternary marine sea-levels are then discussed. During one of the glaciations at least, the sea-level was certainly depressed down to 100 m, probably to 150 m, and perhaps to 200 m or even more. Evidences for this large regression are produced. Drowned valleys and submerged strandlines are still recognizable. Recent techniques allow better investigations of these features. It may be that the sea-level rose temporarily to its present position during an interstade of the Wurm Glaciation; but objections against this view are serious. The rise of the sea-level after the end of the Wurm Glaciation can be followed in detail in some areas, such as The Netherlands and the gGulf and Atlantic coasts of the United States. Much discussion, however, persists about the problem of the maximum level reached by this transgression: some authors think that the sea surpassed by 1-3 m the present datum during the past few thousands of years, whereas others do not accept the evidence represented in this respect. (Author).

124 GUTENBERG, B. 1933. "Tilting Due to Glacial Melting," Journal of Geology, Vol 41, No. 5, pp 449-467.

To investigate tilting and changes interval in the United States and Canada, results from the records of the tide gages of different stations were analyzed. In the Great Lakes region all results indicate a tilting of the land upward in a northerly direction, by about 10 cm per 100 km per century. Along the Pacific coast a small rising of the land is indicated at the north, whereas; California the changes in height seem to be negative, but small and irregular. Along the Atlantic coast of Canada the changes are small and within the limits of error nearly everywhere, but south of Portland (ME) sinking prevails clearly. It is very probable that the tilt in the great Lakes region is due to forces which tend to restore isostatic equilibrium, distributed by the melting of ice after the Ice Age. (Author).

125 GUTENBERG, B. 1941. "Changes in Sea-Level, Postglacial Uplift, and Mobility of the Earth's Interior," Geological Society of America, Bulletin 52, pp 721-772.

Record of tide gages indicate that sea-level generally is rising at an average rate of about 10 cm per century. The uplift in Fennoscandia and North America is investigated, and maps showing the rate of uplift are given. A discussion of the new material and historic evidence leave no doubt that the uplift is a consequence of isostatic readjustment of the equilibrium disturbed by the postglacial melting of the ice. The remaining uplift is about 200 ms in Fennoscandia and possibly more in North America, where the present rate of uplift has its maximum of about 2 ms per century in the region of Hudson Bay. Originally, the time needed to reduce the defect in mass to one half under the regions of uplift was less than 10,000 years, but it has been increasing with time and now exceeds 20,000 years.

Theoretical investigations on the plastic flow in the interior of the earth connected with the uplift are critically discussed and extended. The movements affect the whole interior of the earth below the regions of uplift; their amplitudes decrease slowly in the upper 1000 km. If one assumes a strong lithosphere with a thickness of about 70 km and below the asthenosphere with a viscosity of the order of 10^{22} poises, but little or no strength to prohibit plastic flow, there is no disagreement with observations related to isostasy or deep-focus earthquakes. Tectonic processes connected with isostatic anomalies larger than those in the regions of postglacial uplift must be connected with plastic flow at least down to the core. The importance of the effects of small forces acting during long periods is pointed out. (Author).

126 HACKNEY, C. T., and CLEARY, W. J. 1987. "Saltmarsh Loss in Southeastern North Carolina Lagoons: Importance of Sea-Level Tide and Inlet Dredging," Journal of Coastal Research, Vol 3, No. 1, pp 93-97.

Salt Marshes can maintain themselves during periods of relative sea-level (RSL) rise through accumulation of autochthonous plant biomass and by

capturing sediments. Lagoonal salt marshes in southeastern North Carolina accumulate 358 g $m^2 year^{-1}$ of roots and rhizomes within their sediments. At an average bulk density of 0.3 g cm^{-3} the marsh can vertically accrete 1.2 mm $year^{-1}$. The average RSL rise for the past 40 years was 1.9 mm $year^{-1}$, thus these salt marshes cannot maintain themselves through autochthonous production alone. Large quantities of sand are available to these marshes through inlets and historical data show that marshes disappeared when this sediment source was eliminated. The predicted increase in the rate or RSL and the removal of large quantities of sand for beach renourishment on developed barrier islands may significantly hasten the drowning and disappearance of large areas of salt marsh in the lagoons of southeastern North Carolina. (Authors).

127 **HAGGART, B. A.** 1988. "A Review of Radiocarbon Dates on Peat and Wood From Holocene Coastal Sedimentary Sequences in Scotland," Scottish Journal of Geology, Vol 24, No. 2, pp 125-144.

One-hundred and fifty-eight radiocarbon dates from Holocene coastal sedimentary sequences are assessed in terms of their tendency of relative sea-level movement. Three subdivisions of greater, intermediate and lesser uplift history are made in order to assess the degree of synchroneity or diachroneity present in the data. The most successful demonstration of diachroneity is for the initiation of the mid-Holocene fall in relative sea-level. This may correspond approximately with the formation of the Main Postglacial Shoreline throughout Scotland. (Author).

128 **HALLAM, A.** 1988. "A Reevaluation of Jurassic Eustasy in the Light of New Data and the Revised Exxon Curve," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 262-274.

A comparison is made between the revised Exxon eustatic curve for the Jurassic, based essentially on seismic stratigraphic analysis of North Sea data, and a new curve derived from more conventional stratigraphic analysis. The two curves are broadly similar in that a secular rise of sea-level through most of the period is indicated on which about 17 shorter term cycles are superimposed. Both record notable rises in the Sinemurian, Toarcian, Bajocian, Callovian, Oxfordian, and Kimmeridgian. The Exxon curve, however, misses the important event across the Triassic-Jurassic boundary and underestimates the rate of rise in sea-level for a number of cycles. In addition, some supposed eustatic events can be discounted as the consequence of regional tectonics. Tectonic activity involving subsidence and uplift, rather than geoid changes, is thought to be the principal cause of regional distortions of the global picture. There is a need for better quantitative data on the amplitude and rate of changes in sea-level. (Author).

129 HAMON, B. V. 1962. "The Spectrums of Mean Sea-Level at Sydney, Coff's Harbour, and Lord Howe Island," Journal of Geophysical Research, Vol 67, No. 13, pp 5147-5155.

Daily mean sea-levels for the period July 1957 to December 1958 were first adjusted to correspond to a fixed value of atmospheric pressure. The spectrums and cross spectrums, coherences and phase differences of the adjusted sea-levels were computed for periods between 2 and 60 days. Spectrums of atmospheric pressure were also computed. The atmospheric pressure spectrums contain peaks at periods of 9 and 5 days at all stations. The cross spectrums between adjusted sea-levels at Sydney and Coff's Harbour show high coherence at long periods; they also show that the Sydney series lags the Coff's Harbour series by approximately one day. No explanation could be found for this lag. The coherence between the Coff's Harbour and Lord Howe Island series was low, especially at the longer periods. This is believed to be due to movement of the axis of the east Australian current relative to the island. (Author).

130 HANDS, E. B. 1976a. "Observations of Barred Coastal Profiles Under the Influence of Rising Water Levels, Eastern Lake Michigan, 1967-71," CERC Technical Report 76-1, US Army Corps of Engineers, Fort Belvoir, VA.

Descriptions of lakeshore bathymetry and its temporal variations over a 4-year period are based on 125 shore-normal profiles from 35 stations and aerial photos covering 50 km of shore near Pentwater Harbor on the eastern shore of Lake Michigan. A sequence of four, well-developed, straight longshore bars paralleled the shore. These bars were observed to merge with one another only twice along the entire 50 kilometers, and were persistent year-round features. There was also a temporary coastal bar which displayed at least four distinct aerial patterns.

In wavelength, lacustrine longshore bars overlap with the sand waves from continental shelves; in relief, bars are somewhat smaller (0.1 to 2.2 m). Bar relief equals approximately one-half crest depth or one third trough depth. The upper limit on the cross-sectional area of a given bar is numerically about the same (in square m) as the spacing (in m) between it and the next bar shoreward. As depth decreases toward shore, the cross-sectional dimensions including bar height and spacing, decrease in regular progressions.

Waves were observed to break almost exclusively by spilling, indicating that contrary to previous reports, plunging-type breakers are not necessary for bar development. The frequency of waves breaking on the outer bar was calculated to be about 18 hours per decade, suggesting that the breakers at this depth (averaging 5.3 m) may occur too infrequently to account for observed bar mobility and maintenance.

From 1967 to 1971, the annual mean elevation of Lake Michigan rose 0.5 m. Inner bars north of Pentwater Harbor rose 0.5 m and migrated an average of 26 m landward. The shoreline retreated, under the combined effects of submergence and erosion, at a rate that averaged 4 m per year. Landward migration of longshore bars, exceeded shoreline retreat by 75 percent. This difference may indicate a greater timelag in the response of the upper part of the beach to rising lake levels. Continued monitoring of all profile stations is desirable to determine whether the coupling observed between bars,

shoreline, and lake level at Pentwater is a valid model for other areas of the eastern shore of Lake Michigan. (Author).

131 **HANDS, E. B.** 1976b. "Some Data Points on Shoreline Retreat Attributable to Coastal Subsidence: International Association of Hydrological Sciences," Proceedings of the Anaheim Symposium, pp 629-645.

Coastal subsidence increases flooding in low lying coastal regions. Moreover, it disturbs the equilibrium profile, and allows waves to erode bluffs formerly above the reach of wave uprush. Ensuing adjustment of the profile drives the shoreline farther landward. Guidance is needed for obtaining quantitative estimates of the shore's response.

The mean surface elevation of Lake Michigan rose 0.5 m during a recent four year period. Concurrently, major elements of the submerged profile responded by building upward and migrating 26 m landward. Approximately 8 m of beach were lost due to submergence beneath the elevated lake surface; and an additional 6 to 7 m were lost due to erosion. The shoreline, however, lagged behind the rest of the profile in adjusting to the higher water levels.

Over a longer period, certain sections of Lake Michigan have undergone relative subsidence as a consequence of broad regional tilting of the earth's crust. It is estimated that during the last century the Lake Michigan basin tilted 0.06 to 0.09 m per 100 kilometers along its axis. Shore recession over the last century increased at a rate of 19 ± 10 m per 100 km in the direction of greater subsidence.

Other coastal areas with similar geomorphology and wave exposure can be expected to recede at rates similar to those indicated above if subjected to the same subsidence. The initial response to rapid subsidence may be on the order of 50 units of retreat for each unit of subsidence. Profile retreat is, however, a non-linear, time-dependent function of subsidence, and for slower subsidence, shore-eroded sediments become spread over a broader profile, producing a larger ratio of share retreat per unit of subsidence. Estimates of shore recession due to slow crustal motion of the Great Lakes basin indicate response ratios between 120:1 and 390:1. Furthermore according to the concept of mass balance, the long term response ratio should also depend on the volume and size distribution of sediments being supplied to the nearshore profile by shore erosion. The lakeshore response was found to increase several fold where inadequate backshore deposits supplied less beach material per unit of recession. (Author).

132 **HANDS, E. B.** 1979. "Changes in Rates of Shore Retreat, Lake Michigan, 1967-76," CERC (Coastal Engineering Research Center), Technical Paper No. 79-4, US Army Corp of Engineers, Fort Belvoir, VA, pp 71.

Shorelines tend to retreat landward as water levels rise. Less than 20 percent of the shore, lost as Lake Michigan rose between 1967 and 1976, was due to direct inundation; the remaining 80 percent was due to increased erosion in response to the higher lake levels. A simple correlation of lake level change and simultaneous shore retreat ignores the inevitable lag between process and response, but still accounts for 50 percent of the variance in shore retreat. A graphic summary of field data is presented to estimate effects of future lake level changes in similar coastal environments.

Qualitative guidance is provided on how and when these estimates should be adjusted to reflect differences in environmental settings. Complete adjustment of the shore will be underestimated by the empirical relationship; but where lake levels change constantly, there will be many such instances of incomplete shore response. (Author).

133 **HANDS, E. B.** 1980. "Prediction of Shore Retreat and Nearshore Profile Adjustments to Rising Water Levels on the Great Lakes," Technical Paper No. 80-7, US Army Engineer, Waterways Experiment Station, CERC (Coastal Engineering Research Center), Fort Belvoir, VA, pp 119.

The effects of water level changes on shore recession are particularly important in the Great Lakes because annual mean lake levels often rise rapidly for periods of 5 to 10 years and then decline for a similar number of years. To a limited extent, man can anticipate and influence these fluctuations. Two methods of predicting the response of a beach to such fluctuations are (a) by measuring rates of shore change at certain locations during and after a recent rise in the water surface elevations, and assuming the next change in water level will illicit a similar response, or (b) by balancing sediment gains and losses in a number that would adjust an equilibrium profile to the new water level.

The first method entails a qualitative evaluation of differences in lake level behavior and geomorphic conditions between the study site and the site of application. If mean water levels are predicted to remain at their new elevation long enough for complete profile adjustment, then the second method (sediment balance approach) should be used. The latter approach also accounts for site-specific variations.

Shore recession in response to higher mean water levels involves adjustments which affect a broad area of the nearshore zone. The sediment balance approach provides a realistic model for evaluating the ultimate response of both the shoreline and the nearshore zone to a quasi-permanent change in water levels. This fact was verified by measurements of profile change between 1967 and 1976 along a section of the eastern shore of Lake Michigan. This data set also permitted an evaluation of the timelag between lake level changes and profile readjustment. A relationship between the maximum depth of profile adjustment and the wave climate is proposed which will facilitate application of these results to other locations throughout the Great Lakes. (Author).

134 **HANDS, E. B.** 1981. "Predicting Adjustments in Shore and Offshore Sand Profiles on the Great Lakes," CETA 81-4, US Army Corps of Engineers, CERC (Coastal Engineering Research Center), Fort Belvoir, VA, pp 25.

This report summarizes a procedure for calculating the ultimate advance or retreat of the beach profile in response to a semi-permanent change in water level elevation. The method, applicable to sandy shores throughout the Great Lakes, is illustrated by two examples. Hands (1980) describes the development of the procedure. A strictly empirical correlation useful for estimating shore retreat on a 1- to 5-year basis is discussed in Hands (1979). The present procedure couples field measurements with a model of how the profile ultimately reestablishes equilibrium with a new water level elevation.

The former procedure would generally underestimate this longer term change. (Author).

135 **HANDS, E. B.** 1984. "The Great Lakes as a Test Model for Profile Response to Sea-Level Changes," US Army Corps of Engineers, CERC (Coastal Engineering Research Center), Miscellaneous Report, CERC-84-14, pp 26.

The average annual water level on Lake Michigan rose 0.8 m between 1967 and 1973 causing adjustments in nearshore processes and topography. Assuming 2 mm/year as a typical rate for sea-level rise, it would take 400 years to observe similar adjustments on an ocean beach. The rapid rise in average water level is one of several features that makes the Great Lakes useful for testing concepts of shore response to sea-level changes.

The key assumption in the Bruun concept of response to sea-level rise is that the same average beach profile is reestablished relative to the higher water elevation. This assumption was confirmed by detailed measurements over a 9-year period of 25 beach and offshore profile transects along 50 km of Lake Michigan shoreline. Complete profile adjustment lagged 3 years behind the water level change.

A simple equation was developed expanding Bruun's concept to account for (a) gains and losses of sediment from causes other than the water level variation, (b) erosion of different size sediments in the receding shoreface, not all of which would be stable in the shore zone, and (c) accretion of beach material during falling water levels.

The expanded Bruun sediment balance approach reduces the problem of estimating long-term shore response to sea-level rise to the simpler problem of determining an appropriate closure depth for the responding profile. In the Great Lakes, this closure depth can be estimated as about twice the 5-year return-period wave height for the site under consideration. Use of a closure estimate based on a Froude Number, similar to Hallermeier's offshore limit, may improve transfer of the expanded Bruun approach to those areas of the ocean shore exposed to longer period storm waves. (Author).

136 **HANSEN, J., JOHNSON, D., LACIS, A., LEBEDEFF, S., LEE, P., RIND, D., RUSSELL, G.** 1981. "Climate Impact of Increasing Atmospheric Carbon Dioxide," Science, Vol 213, No. 4511, pp 957-966.

The global temperature rose by 0.2° C between the middle 1960's and 1980, yielding a warning of 0.4° C in the past century. This temperature increase is consistent with the calculated greenhouse effect due to measured increases of atmospheric carbon dioxide. Variations of volcanic aerosols and possibly soar luminosity appear to be primary causes of observed fluctuations about the mean trend of increasing temperature. It is shown that the anthropogenic carbon dioxide warming should emerge from the noise level of natural climate variability by the end of the century, and there is a high probability of warming in the 1980's. Potential effects on climate in the 21st century include the creation of drought-prone regions in North America and central Asia as part of a shifting of climatic zones, erosion of the West

Antarctic ice sheet with a consequent worldwide rise in sea-level, and opening of the fabled Northwest Passage. (Summary).

137 **HANSEN, J., LACIS, A. and RIND, D.** 1983. "Climate Trends Due to Increasing Greenhouse Gases," Proceedings of Coastal Zone '83, Third Symposium on Coastal and Ocean Management, American Society of Civil Engineering, Vol III, pp 2796-2810.

Climate models indicate that global mean temperature should increase 3 ± 1.5°C if atmospheric CO_2 is doubled. A broad range of empirical evidence, ranging from the climate on other planets to paleoclimate and recent climate trends on the earth, is consistent with the climate sensitivities indicated by the climate models. After reviewing the evidence, we conclude that there is strong evidence that a doubling of atmospheric CO_2 will lead to a global climate warming of at least 1.5°C. Such an increase will correspond to a climate state near or beyond the range of human experience.

The time required to reach an effective doubling of atmospheric CO_2 is reduced by trace gases such as methane and the chlorofluorocarbons, which have begun to increase at substantial rates during the past two decades. The contribution of trace gases to the atmospheric greenhouse effect is now comparable to that of CO_2. If current trends of atmospheric composition continue, effective doubling of CO_2 will occur in several decades. Based on the consensus estimate for climate sensitivity, it appears likely that substantial climate change due to the greenhouse warming will become apparent during the next 1-2 decades. The authors recommend climate model studies as high priority research. It is particularly important that climate models include regional climate simulation with emphasis on slowly changing atmospheric composition. (Modified Abstract).

138 **HANSEN, J., RUSSELL, G., LACIS, A., FUNG, I., RIND, D. and STONE, P.** 1985. "Climate Response Times: Dependence on Climate Sensitivity and Ocean Mixing," Science, Vol 229, No. 4716, pp 857-859.

The factors that determine climate response times were investigated with simple models and scaling statements. The response times are particularly sensitive to (i) the amount that the climate response is amplified by feedbacks and (ii) the representation of ocean mixing. If equilibrium climate sensitivity is 3°C or greater for a doubling of the carbon dioxide concentration, then most of the expected warming attributable to trace gases added to the atmosphere by man probably has not yet occurred. This yet to be realized warming calls into question a policy of "wait and see" regarding the issue of how to deal with increasing atmospheric carbon dioxide and other trace gases. (Authors).

139 **HAG, B. U., HARDENBOL, J., and VAIL, P. R.** 1987. "Chronology of Fluctuating Sea-Levels Since the Triassic," Science, Vol 235, pp 1156-1167.

Advances in sequence stratigraphy and the development of depositional models have helped explain the origin of genetically related sedimentary packages during sea-level cycles. These concepts have provided the basis for the recognition of sea-level events in subsurface data and in outcrops of marine sediments around the world. Knowledge of these events has led to a new generation of Mesozoic and Cenozoic global cycle charts that chronicle the history of sea-level fluctuations during the past 250 million years in greater detail than was possible from seismic-stratigraphic data alone. An effort has been made to develop a realistic and accurate time scale and widely applicable chronostratigraphy and to integrate depositional sequences documented in public domain outcrop sections from various basins with this chronstratigraphic framework. A description of this approach and an account of the results, illustrated by sea-level cycle charts of the Cenozoic, Cretaceous, Jurassic, and Triassic intervals, are presented. (Authors).

140 **HAQ, B. U., HARDENBOL, J., and VAIL, P. R.** 1988. "Mesozoic and Cenozoic Chronostratigraphy and Cycles of Sea-Level Change," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 71-108.

Sequence-stratigraphic concepts are used to identify genetically related strata and their bounding regional unconformities, or their correlative conformities, in seismic, well-log, and outcrop data. Documentation and age dating of these features in marine outcrops in different parts of the world have led to a new generation of Mesozoic and Cenozoic sea-level cycle charts with greater event resolution than that obtainable from seismic data alone. The cycles of sea-level change, interpreted as having been found in response to sea-level fluctuations, can be tied into the chronostratigraphy.

Four cycle charts summarizing the chronostratigraphy, coastal-onlap patterns, and sea-level curves for the Cenozoic, Cretaceous, Jurassic, and Triassic are presented. A large-scale composite-cycle chart for the Mesozoic and Cenozoic is also included (in pocket). The relative magnitudes of sea-level falls, interpreted from sequence boundaries, are classified as major, medium, and minor, as are the condensed sections associated with the intervals of sediment starvation on the shelf and slope during the phase maximum shelf flooding during each cycle. Generally only the sequence boundaries produced by major and some medium-scale sea-level falls can be recognized at the level of seismic stratigraphic resolution; detailed well-log and/or outcrop studies are usually necessary to resolve the minor sequences. (Authors).

141 HARRIS, D. L. 1981. Tides and Tidal Datums in the United States, U.S. Army Corps of Engineers, CERC (Coastal Engineering Research Center), Special Report No. 7, pp 382.

The boundary between sea and land appears to be the natural datum of reference for measuring elevation of land or depth of the sea. This boundary, however, varies continuously because of the astronomical tides and for other reasons. The various factors which cause this variability are discussed with emphasis on the astronomical tides as the most predictable of the phenomena which affect sea-level.

Several tidal datums of practical importance are described. Sources of detailed information are identified. Difficulties associated with surveys which extend over a wide range of latitude and elevation are discussed.

Statistical characteristics of the astronomical tides at various U.S. ports are investigated and documented with graphs and tables. The distribution function for astronomical tidal heights is found to be nearly symmetric at many stations. At many other continental tide stations, the astronomical tide remains above mean sea-level (MSL) more than half the time, but departs farther from MSL in a negative rather than in a positive direction. At Honolulu, Hawaii, the predicted tide is below the MSL more than half the time and positive departures are larger than negative departures.

A technical glossary and supplementary tables are included. (Author).

142 HARRISON, W., MALLOY, R. J., RUSNAK, G. A., AND TERASMAE, J. 1965. "Possible Late Pleistocene Uplift Chesapeake Bay Entrance," Journal of Geology, Vol 73, No. 2, pp 201-229.

Paleontological and lithological studies of engineering borings and boring logs indicate that a buried, subaerial erosion surface of Pliocene (?) - Pleistocene age cuts across clastic sediments of pre-Yorktownian Miocene age in the subsurface and subbottom of the lower Chesapeake Bay area. When the bore-hole data are coupled with the results of subbottom of the lower Chesapeake Bay area. When the bore-hole data are coupled with the results of subbottom echo profiling and piledriving records, it is possible to construct accurate cross sections of the buried Miocene-Pleistocene contact. The cross sections show "lows" in the erosion surface that may be correlated with the buried channels of the Pleistocene Elizabeth, James, York, and Susquehanna river valleys. Probable channel depths below mean low water at control points are: 100 ft (Elizabeth River, beneath Tunnel No. 1), 155 ft (James River, at Hampton Roads Tunnel), 120 ft (York River, at Yorktown), 158 ft (Susquehanna River, off Cape Charles City), and 160 ft (Susquehanna River, at Fisherman Island, Cape Charles). The channel depths of what is believed to be the buried Susquehanna River Valley are less than expected when placed on a curve showing the expectable gradients of that stream during the time of the most recent, maximum lowering of sea-level (ca. 18,000 years B.P.). The discrepancy suggest uplift of that channel of approximately 170 ft in about the last 18,000 years. Pollen analysis and C^{14} dating of peats and shells immediately overlying the Miocene-Pleistocene contact indicate that the peats were deposited in brackish-water marshes or on boreal flood plains, probably only slightly above sea-level, and that they were subsequently submerged and covered by estuarine sediments. The peats date between 10,340 and 15,280 years B.P., and occur at depths of 82-89 ft below mean low rise of sea-level on relatively stable coasts, it seems possible that the peats may have been uplifted as much as 160 ft in the last 15,000 years.

Additional possible evidence of uplift within the last 1,900 years also is suggested by C^{14} dates on a peat and underlying shell bed cropping out on the seaward side of Hog Island on Virginia's eastern shore: The peat bed, assumed to have formed at about high tide, and the shell bed, deposited below low tide, now crop out some 5 ft above mean low water, and date from 1170 to 1900 years B.P., respectively.

Rates of uplift suggested by three localities of dated horizons indicate an average value of about 1.05 ft per century for the past 15,000 years, although the rate of uplift varied with time and actually involves a calculation for subsidence between 6,000 and 2,000 B.P. The rate of uplift seems to have approximated the rate of eustatic sea-level rise (about 2.8 ft per century), between 15,000 and 8,000 B.P. Apparent reversal of crustal uplift between about 6,000 and 2,000 B.P., coupled with continued eustatic rise of sea-level, allowed for extensive flooding of the Susquehanna valley lowland and eastern shore of Virginia.

Crustal uplift appears to have resumed between 2,000 B.P. and the present. The crustal-movement curve for the period 14,000-3,000 B.P. is remarkably similar to that found by Kaye and Barghoorn (1964) for the Boston area. (Authors).

143 **HAYDEN, B. P.** 1984. "A Systematic Error in the Northern Hemisphere Sea-Level Pressure Data Set," Monthly Weather Review, Vol 112, No. 11, pp 2354-2357.

The Northern Hemisphere daily sea-level pressures at 5° latitude/-longitude grid intersections for the years 1899-1980 are extensively used by researchers. Changes in the basis of this grid-point data record are given in Trenberth and Paolino (1980). They also document 3263 "serious" errors. For the most part these errors were over Asia in the years before 1922 and during World War II. Recently a search was done of the daily pressure data tape and recorded frequency of centers of low pressure for the Northern Hemisphere. This process uncovered a complex but hemispherically systematic error in this data that may pose problems when using certain types of analyses. The details of this bias, its source and when it is likely to be encountered are presented here as an addendum to Trenberth and Paolino's benchmark work. (Introduction).

144 **HICKS, S. D.** 1972a. "On the Classification and Trends of Long Period Sea-Level Series," Shore and Beach, Vol 83, No. C3, pp 1377-1379.

The dramatics of surf and longshore currents in the beach erosion process overshadows the small but relentless changes in sea-level over years and decades. Yet, these same variations in sea-level are the very agents that prevent beach erosion-building equilibria. As such, it behooves those interested in shore and beach preservation to attempt to understand yearly variability and long period trends in sea-level and, hopefully, to predict future levels.

The present status of long period sea-level studies is: descriptions for many areas including the United States, qualitative understanding of

variability, quantitative understanding at selected locations, and quantitative understanding for selected parameters.

This paper presents for the United States: the most recent yearly mean sea-level data available (in graphic form), a summary of classifications, and apparent secular trend calculations for the 31-year series, 1940 to 1970 at all stations. It is essentially an updating of the previous Shore and Beach paper by Hicks (1968). (Author).

145 **HICKS, S. D.** 1972b. "Vertical Crustal Movements From Sea-Level Measurements Along the East Coast of the United States," Journal of Geophysical Research, Vol 77, No. 30, pp 5930-5934.

The rate of coastal subsidence relative to southern Maine is found to increase linearly a total of 0.214 cm/year from southern Maine to Hampton Roads, Virginia. The absolute rate of subsidence closely approximates the relative rate. Since sea-level at Portland, Maine is rising at a rate close to the estimated value for the rate of the glacial-eustatic rise. A marked discontinuity occurs in the vicinity of Cape Hatteras, south of which there appears to be no significant vertical land movement. The results are based on 23 yearly mean sea-level series, each from 1939 through 1970. (Author).

146 **HICKS, S. D.** 1978. "An Average Geopotential Sea-Level Series For the United States," Journal of Geophysical Research, American Geophysical Union, Vol 83, No. C3, pp 1377-1379.

For climate monitoring purposes an average sea-level series for the United States, from which a representative curve and a single-value rate were derived, is presented. In addition, the use of dynamic height is introduced in order to take into account the greatly differing latitudes of the tide stations used in the study. The series was obtained by averaging common length uninterrupted sea-level elevations reduced from the tide gage measurements of each station. The averaging was by coastal area. The curve, with amplitudes of the averaged meteorological and oceanographic oscillations of periods of less than 5-1/3 year attenuated more than 90%, shows the relative apparent secular trend and its changes for the United States as a whole. During the 36-year period, 1940-1975, sea-level rose along the coast of the United States at the average rate of 1.5 dynamic mm/year. (Authors).

147 **HICKS, S. D., DEBAUGH, H. A., JR., and HICKMAN, L. E., JR.** 1983. Sea-Level Variations for the United States, 1855-1980, National Oceanic and Atmospheric Administration, Rockville, MD, pp 170.

An introduction to the study of sea-level and its applications are presented. Trends, their standard errors, and annual variabilities are computed for 44 US stations that are permanent, continuous, and were in operation before 1940. The computations are for the entire length of series at each station and for the common series length, 1940 through 1980. Trends, their

standard errors, and annual variabilities also are computed for five area means and the US mean. Graphs of area means, the US mean, and 67 individual stations are depicted, the latter for both yearly and monthly mean sea-level. Monthly and yearly mean sea-level data are tabulated for the entire length of series at the 67 stations. (Authors).

148 HICKS, S. D., and SHOFNOS, W. 1965. "The Determination of Land Emergence From Sea-Level Observations in Southeast Alaska," Journal of Geophysical Research, Vol 70, No. 14, pp 3315-3320.

Sea-level observations in southeast Alaska show a maximum rate of land emergence relative to the level of the sea of 3.96 cm/year at Bartlett Cove, Glacier Bay. A conservative estimate of total maximum emergence, based on direct observations, is 154 cm from 1922 to 1960. Land emergence at rate greater than 1.9 cm/year is found within an area roughly bounded by Skagway, Juneau, the outer coast, and a north-south line located about half-way between the head of Glacier Bay and Yakutat. The area of emergence is reniform, with its major axis oriented in a north-south direction. Its steepest slopes lie to the south and west. The feature appears to be the result of rebound from present localized deglaciation or the combination of present localized and general post-Wisconsin deglaciation. The study is based on 28 separated series of sea-level observations extending as far back as 1887 and 5 continuous series, the oldest extending back to 1919. The oldest series of observations within the 1.9 cm/year emergent zone dates from 1902. (Authors).

149 HOFFMAN, J. S., KEYES, D., and TITUS, J. G. 1983. "Projecting Future Sea-Level Rise, Methodology, Estimates to the Year 2100 and Research Needs," Environmental Protection Agency Report 230-09-007, pp 121.

Concentrations of atmospheric CO_2 and other greenhouse gases will continue to increase in coming decades. Two National Academy of Sciences panels have concluded that higher levels of these gases will almost certainly produce a large global warming. That warming, by thermally expanding the oceans and by causing the transfer of ice and snow resting on land to the oceans, should raise sea-level substantially faster than the rise that has taken place during the past century.

Although current knowledge is inadequate to make a precise prediction of future sea-level rise, it is sufficient to predict the likely range. Many factors were considered in generating the estimates of sea-level rise contained in this report: population and productivity growth, atmospheric and climatic change, and oceanic and glacial response. High and low assumptions for these principal determinants of sea-level rise were derived from the literature. When linked together the various assumptions allowed the estimation of high and low paths of future sea-level rise. (Report Summary).

150 HOLDAHL, S. R. and MORRISON, N. L., 1974. "Regional Investigations of Vertical Crustal Movements in the U.S., Using Precise Relevelings and Mareograph Data," In: R. Green (Editor), Recent Crustal Movements and Associated Seismic and Volcanic Activity, Tectonophysics, Vol 23, No. 4, pp 373-390.

In the past two years, the National Geodetic Survey has been creating a data base of vertical crustal movement information. The data elements are relative elevation changes along lines of releveling which are used to produce graphic displays on microfilm. In separate studies, the releveling data, together with information extracted from mareograph records, have been used to create two networks of velocity differences. The two networks one in the vicinity of Chesapeake Bay and the other covering the Gulf Coast states, have been adjusted in order to prepare maps showing the velocities of elevation change. In the adjustments, the velocities derived from mareograph records were treated as observations. The results indicate annual subsidence ranging between -1.2 mm and -4.0 mm in the Chesapeake Bay area, with significant local variation. In the Gulf Coast region there is generally slight subsidence along the coast, ranging between 0.0 and -1.5 mm/year. Stability and slight uplift is indicated to the north where bedrock reaches the terrain surface. Anomalous subsidence of -7.0 mm/year occurs at New Orleans, Louisiana, and at Houston, Texas, there has been several decimeters change in the last ten years. (Authors).

151 HOPLEY, D. 1984. "The Holocene 'High Energy Window' on the Central Great Barrier Reef," In: Coastal Geomorphology in Australia (edited by B. G. Thom), pp 135-150.

The concept of a Holocene 'high energy window' was introduced by Neumann (1972). He suggested that on tropical coasts during the mid-Holocene, a period of higher wave energy may have existed during the period when the present level of the sea was being first approached by the Holocene transgression and prior to the protective development of hermatypic coral reefs. It has also been postulated (Stoddart et al., 1978; Hopley, 1982) that the 'window' may have operated on a more local scale on individual reefs with waves breaking not on margins of an extensive reef flat as at the present time, but more extensively over a shallowly submerged reef top prior to the development of the reef flat. This paper examines the concept of a period of a higher wave energy on the central Great Barrier Reef in the mid-Holocene and considers some of the implications for coastal geomorphology. (Author).

152 HOUGHTON, R. A. and WOODWELL, G. M. 1989. "Global Climatic Change," Scientific American, Vol 260, No. 4, pp 36-44.

This article emphasizes the role of carbon dioxide and methane in global warming. The authors suggest that production of carbon dioxide and methane from human activities has already begun to change the climate and that radical steps must be taken to halt any further change. A series of key graphs

correlate the global temperature change, level of heat-trapping gases and carbon dioxide emission for the past 140 years. (Gorman).

153 **HOWARD, J. D., KAUFMAN, W., and PILKEY, O. H.** 1985. "Strategy for Beach Preservation Proposed," Geotimes, Vol 30, No. 12, pp 15-19.

The authors present a guide to public policy of retreat along the American shoreline. Recommendations are made to the private sector and different levels of government. The text is adapted from a position paper that is the result of the Second Skidaway Institute of Oceanography Conference on America's Eroding Shoreline. (Gorman).

154 **HSIEH, W. W.** 1985. "Modal Bias in Sea-Level and Sea Surface with Applications to Remote Sensing," Journal of Physical Oceanography, Vol 15, pp 351-356.

From vertical normal mode decomposition, sea-level and sea surface temperature (SST) are shown to be modally biased-higher modes are suppressed in sea-level while lower modes are suppressed in SST data. Having been effectively "low passed" and "high passed" (with respect to mode number) by nature, sea-level and SST contain complementary information which can in principle be combined to yield a relatively unbiased picture. The full potential of the sea-level-SST pair is not appreciated in present remote sensing studies, where the two are used separately. A proposed "stereoscopic" method may in the future produce unbiased three-dimensional pictures from satellite-sensed two-dimensional pictures of sea-level and SST. Modal bias in coastal trapped waves is studied in the Appendix. (Author).

155 **HULL, C. H. J., and TITUS, J. G. (eds).** 1986. Greenhouse Effect, Sea-Level Rise, and Salinity in the Delaware Estuary, United States Environmental Protection Agency, Washington, DC, pp 88.

Increasing atmospheric concentrations of carbon dioxide and other gases are expected to warm the earth a few degrees (C) in the next century by a mechanism commonly known as the "greenhouse effect." Such a warming could alter precipitation patterns and raise sea-level. Although it is not yet possible to predict whether particular areas will receive more or less rainfall, there is a general agreement that sea-level will rise. Unfortunately, estimates for the year 2025 range from 5 to 21 inches above current sea-level, while estimates of the rise by 2100 range from 2 to 11 ft.

Several issues must be resolved for society to rationally address the possibility of significant changes in climate and sea-level. Officials making decisions about near-term projects with long lifetimes must examine the potential consequences and determine whether these risks justify a shift to strategies that are less vulnerable to changes in sea-level or the frequency or severity of droughts. Research officials must assess the opportunities for improving predictions and decide whether the need for these improvements

justifies accelerating the necessary research. Decision makers must decide whether to base policies on today's inadequate knowledge or ignore the implications until they are more certain.

One potential impact of a global warming and rise in sea-level would be an increase in the salinity of estuaries, which might threaten drinking water and aquatic ecosystems. The Delaware River Basin Commission (DRBC) has long considered the implications of droughts on management of water resources in the Delaware estuary; since 1979, it has also considered the implications of recent sea-level trends. However, the DRBC has not previously focused on the possibility that the "greenhouse warming" could exacerbate salinity problems. The Environmental Protection Agency has initiated studies on the impacts of sea-level rise and climate change on erosion, flooding, and wetland protection, but has not previously examined the impacts on salinity.

This joint report by the Environmental Protection Agency and the Delaware River Basin Commission examines the implications of the greenhouse warming for salinity control in the Delaware estuary. The study focuses on the implications of (1) a 21-inch rise in global sea-level expected by 2050, which would imply arise of 2.4 ft in the Delaware estuary; and (2) a 7-ft global rise by 2100, which would imply an 8.2-ft rise in the Delaware estuary. The authors estimate the increase in estuary salinity, estimate the possible increase in salinity of the Potomac-Raritan-Magothy aquifer system, discuss the implications, and examine possible responses. Potential changes in precipitation are not evaluated. (Summary).

156 **HULL, C. H. J., and TORTORIELLO, R. C.** 1979. "Sea-Level Trend and Salinity in the Delaware Estuary," Staff paper, Delaware River Basin Commission, West, Trenton, NJ, pp 19.

In 1954, the United States Supreme Court authorized the City of New York and the State of New Jersey to divert water from the Delaware River Basin. New York City was permitted to take water at a yearly average rate not to exceed 800 mgd provided certain compensatory releases from storage reservoirs were made to the Delaware River for protection of downstream water quality. The State of New Jersey was authorized to divert the equivalent of 100 mgd as a monthly average, with the diversion on any day not to exceed 120 million gallons.

During the drought of the 1960s, it became clear that the runoff from the drainage area above New York City's Delaware Basin impoundments was not great enough to provide both the authorized diversion and the decreed downstream releases. At that time, the Comprehensive Plan for water resources development in the Delaware River Basin included a series of authorized storage reservoirs that would have offset the water deficit projected for a future drought equal in severity to that of the sixties. However, in the seventies, some of the authorized projects became controversial, and currently at least two of these, including the largest in the Comprehensive Plan, are not considered viable for a planning horizon of 20 years ahead (year 2000). Because of the projected water deficit for a recurrence of a severe drought, the parties to the 1954 Supreme Court decree agreed in early 1979 to negotiate in good faith to determine how best to allocate the increasingly scarce water resources of the Delaware Basin.

In connection with these "good-faith" negotiations, the staff of the Delaware River Basin Commission (DRBC) was asked to provide answers to various questions pertaining to the need for regulation of Delaware River flows at Trenton to control water quality in the Delaware estuary, and in particular to control salinity intrusion. Answers to some of these questions were provided with the aid of a deterministic, time-varying, mathematical model developed for DRBC by Thatcher and Harleman (1978). This model can be used to predict changes in salinity caused by such factors as depletive water use, including both in-Basin consumptive use and out-of-Basin diversions, streamflow regulation by impoundments , and changing sea-level.

The purpose of this paper is to examine the potential effect on Delaware estuary salinity of a rising sea-level at the mouth of Delaware Bay. (Introduction).

157 INQUE, M., and O'BRIEN, J. J. 1987. "Trends in Sea-Level in the Western and Central Equatorial Pacific During 1974-1975 to 1981," Journal of Geophysical Research, Vol 92, No. C5, pp 5045-5051.

The sea-level records at the nine island stations located in the western and central equatorial Pacific show trends for the period 1974-1975 to 1981 which are well hindcasted by the linear numerical model of Busalacchi and O'Brien forced by the observed ship winds. The spatial pattern of these trends suggests that the western equatorial Pacific was losing water while the central equatorial Pacific was gaining water. These trends appear to be due to the significant weakening of the near-equatorial easterly trades in the central Pacific which took place throughout the period 1974-1981. The trend reversal observed in 1977-1978 in sea-level at the island stations located south of the equator (Rabaul and Honiara) appear to be due to a similar trend reversal in the strength of the large-scale southeast trades. (Authors).

158 JAMES, L. D., BOWLES, D. S., and ISRAELSEN, E. K. 1985. "The Use of Hydrologic Data on the Economic and Financial Analysis of Lake Level Control Alternatives," Problems of and for Predicting Great Salt Lake Levels Proc., Center of Public Affairs, Univ. of Utah, pp 261-277.

The rising surface of the Great Salt Lake is forcing increasing numbers of property owners to decide between protecting their holdings or moving out. Federal, state, and local governments are considering levees to protect critical facilities, lake level control through pumping to the West Desert, and through water development to increase consumptive use. Both private and public choices are being made with uncertainty as the lake could rise to cause devastating damage or recede harmlessly. Governmental agencies know that many people face economic disaster if they fail to act and the lake continues to rise. Action is expensive; and if the lake falls, the agencies face charges of poor management. We must recognize that while we cannot predict when flooding will occur (through continuation of the present rise or during some future event), we can express risk with a probability distribution, estimate damages in expected values and compare the expected reduction in damages with costs. (Authors).

159 JERVEY, M.T. 1988. "Quantitative Geological Modeling of Siliciclastic Rock Sequences and Their Seismic Expression," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 47-70.

In order to clarify the principles that govern the development of siliciclastic sequences and their bounding surfaces, a mathematical model of progradational basin filling was created for Atlantic-type continental margins. This paper discusses the model and its implications with respect to depositional facies, sandstone geometry, and seismic stratigraphic interpretation. Basin filling is modeled as the interaction of subsidence, change in sea-level, and sediment influx. The simulations show that seismic-sequence boundaries are located, in time, near inflection points of eustatic sea-level fluctuation, where rates of fall or rise are maximized. Changes in the rate of accommodation development, both in time and space, are believed to play a dominant role in shaping the internal facies distribution, the geometry, and the nature of the bounding surfaces of depositional sequences. The pattern of coastal onlap and offshore condensed sections displayed by global-cycle charts are shown to develop in the context of smoothly fluctuating eustatic and relative sea-level. (Authors).

160 JONES, J. R., and CAMERON, B. 1977. "Landward Migration of Barrier Island Sands Under Stable Sea-Level Conditions, Plum Island, Massachusetts," Journal of Sedimentary Petrology, Vol 47, No, 4, pp 1475-1483.

The origin and development of barrier islands systems has received much attention during the last decade as marine scientists have become more concerned with coastal environments. Plum Island, part of a barrier island system located off the northeastern coast of Massachusetts where sea-level is believed to have remained stable for the last three thousand years, was selected to test the hypothesis that dune migration and longshore sediment transport patterns are causing its landward (west) development and migration, rather than the commonly accepted "rising sea-level hypothesis." Ninety-four surface sand samples taken from the top 2 to 3 inches (5-7 cm) and 94 subsurface sand samples from a 3-ft depth (1 m) were collected for statistical size analysis along six east-west traverses at one mile intervals perpendicular to the island. Trend surface analysis was then performed with the graphic mean size values from the surface and subsurface samples to determine any consistent stratigraphic and geographic textural shifts between the surfaces. Comparison of the third-order surface indicates that the graphic mean grand size generally coarsens from the subsurface to surface. This shift appears to indicate that there is a general landward (west) shift through time in the graphic mean size distributions from the older subsurface to the younger surface. This shift is interpreted to be a direct response of the dune field to the predominant northeasterly storm conditions modified by longshore currents in an area of stable sea-level. It is therefore concluded that a rising sea-level is not necessary for barrier island migration landward. (Authors).

161 KAFRI, URI. 1984. "Current Subsurface Seawater Intrusion to Base Levels Below Sea-Level," Environmental Geology, Water Sciences, Vol 6, No. 4, pp 223-227.

The Imperial Valley, Jordan-Dead Sea Rift, and the Afar and Qattara depressions, all regions below sea-level and the only regions in the world so situated, are characterized by saline and hypersaline groundwater and lakes, phenomena that to date have been solely attributed to ancient lagoons, salt dissolution, and evaporation. Current subsurface seawater intrusion is herewith suggested as an additional mechanism responsible for the salination of these regions. This type of dynamic seawater flow is feasible where there is (a) a base level below sea-level with a hydrological continuity between the two levels, and (b) a low groundwater divide between the base levels with a shallow seawater/freshwater interface situated above the base of the aquifer. (Author).

162 KALININ, G. P., and KLIGE, R. K. 1973. "Level of Closed Bodies of Water as One of the Criteria of Global Water Exchange," Soviet Hydrology, Selected Papers, Vol 6, pp 534-538.

The authors compared the level of large closed lakes to ocean levels. An analysis of lake fluctuations in the last century showed a definite decrease, whereas ocean levels increased within the same time interval. From 1910 to 1968, the ocean level rose at an average rate of about 1.5 millimeter/year. This recent ocean transgression corresponds to an annual withdrawal of continental water reserves of about 550 km^3. (Gorman).

163 KANA, T. W., MICHEL, J., HAYES, M. O., and JENSEN, J. R. 1983. "Shoreline Changes Due to Various Sea-Level Rise Scenarios," Proceedings of Coastal Zone '83, Third Symposium on Coastal and Ocean Management, Vol III, pp 2768-2776.

General methods were developed to assess the effects of various accelerated sea-level rise scenarios on changes in the shore formation, changes in the frequency and depth of flooding from storm surges, and saltwater intrusion into potable aquifers. These methods were developed and applied to the Charleston (South Carolina) area in a case study, with sea-level rise scenarios of 11-232 cm (0.4-7.6 ft) for the years 2025 and 2075. Maps were made to show the predicted changes with little shoreline change even using mean spring high water. (Modified Abstract).

164 KEARNEY, M. S., and STEVENSON, J. C. 1985. "Sea-Level Rise and Marsh Vertical Accretion Rates in Chesapeake Bay," Proceedings of Coastal Zone '85, Fourth Symposium on Coastal and Ocean Management, pp 1451-1461.

Chesapeake Bay marshes, in their wide variety of vegetation types, salinity ranges, and environmental settings provide a unique perspective on

the relations between marsh vertical accretion rates and sea-level rise in a relatively small geographic area. Estuarine marshes, occurring along the meanders in the sediment trap portions of major Bay tributaries, appear at least to be keeping abreast of rising sea-levels. In some marshes, vertical accretion rates may be exceeding local rates of sea-level rise. Although little data are presently available on the actual processes in these marshes, the increased sediment yield of the estuaries following European settlement, probably has helped maintain the accretionary balance with respect to sea-level rise.

The other general type of Chesapeake Bay marsh, submerged upland marshes, may be experiencing an accretionary deficit. These marshes, formed by the gradual submergence of low-lying terraces on the Delmarva mainland, are often characterized by large interior ponds. Studies at Blackwater Wildlife Refuge on Maryland's Eastern Shore, where dramatic losses of marsh from pond enlargement have occurred, indicate that local marshes are not maintaining elevation with sea-level rise. Low vertical accretion rates of these and possibly other submerged upland marshes is a function of the reliance on peat deposition as the primary mechanism of accretion. The physiological consequence of increasing marsh submergence is a decline in marsh production leading to the disintegration of the peat material, and eventually to the formation of interior ponds which enlarge with time. (Modified Abstract).

165 **KELLER, G., HERBERT, T., DORSEY, R., D'HONDT, S., JOHNSON, M. and CHI, W.R.** 1987. "Global Distribution of Late Paleogene Hiatuses," Geology, Vol 15, pp 199-203.

Six global late Paleogene hiatuses)PHa to PHe) have been identified from deep-sea sequences. These hiatuses occurred at the middle/late Eocene boundary, late Eocene, Eocene/Oligocene boundary, late early Oligocene, late Oligocene, and Oligocene/Miocene boundary horizons.

Paleodepth distribution of hiatuses shows hiatus maxima characterized by major mechanical erosion below 4800 m, at mid-depth between 2000 and 3000 m, and in shallower water suggest that flow paths of major water masses and currents are the principal cause. Wide spread short hiatuses due to carbonate dissolution or nondeposition occurred primarily during global cooling trends or climatic instability and appear to correlate to sea-level transgressions or onlap sequences. These hiatuses may have been caused by basin-shelf fractionation of carbonates. (Authors).

166 **KELLETAT, D.** 1988. "Zonality of Modern Coastal Processes and Sea-Level Indicators," Palaeogeography, Palaeoclimatology, Palaeoecology, pp 219-230.

Unlike textbooks on inland geomorphology, most of those on coastal geomorphology give the impression that the formation of the coasts is influenced by processed that are azonal or ubiquitous. Based on quite wide-ranging field studies all over Europe, North Africa, the Middle East, North America, Australia and New Zealand some deductions are presented which in several ways indicate that coastal formation is subject to zonal dynamics. As indicators of the presently active processes a variety of minor forms can be

used, and particularly biological ones which, being bound to certain tide levels, can be reliable indicators of sea-level changes as well. Zonality is particularly well shown by the varied distribution of climate-dependent indicators of sea-level which in addition allows us to quantify sea-level fluctuations and changes of the tidal range. (Author).

167 KENDALL, C. St. C., and LERCHE, I. 1988. "The Rise and Fall of Eustasy," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 3-18.

Techniques that can be used to determine the relative magnitude of eustatic excursions include the measurement of: (a) the amount of sedimentary onlap onto the continental margins; (b) the thickness of marine sedimentary cycles and the elevation and distance between indicators of old strandlines; (c) the perturbations on individual thermo-tectonic subsidence curves and stacked crustal subsidence curves; (d) the variations in deep-ocean oxygen isotopes found in sediments; and (e) the size of variables, such as rates of tectonic movement, sediment accumulation, and eustatic changes, used in graphical and numerical simulations of basin fill that "invert" the problem. To date, a combination of some or all of these methods can be used to construct relative (tectono/eustatic) sea-level curves; however, these are not unique solutions to absolute eustatic variations. Each method assumes some behavior for two of the three underlying processes (tectonic movement of the basement, sedimentary accumulation, and eustasy), and then determines the third process relative to the assumed model behavior of the other two. The sense of this result is confirmed by mathematical models which suggest that only the sum of tectonic basement subsidence and sea-level variations can be obtained. (Authors).

168 KENDALL, G. St. C., and SCHLAGER, W. 1981. "Carbonates and Relative Changes in Sea-Level," In: M.B. Cita and W.B.F. Ryan (Editors), Carbonate Platforms of the Passive-Type Continental Margins, Present and Past, Marine Geology, Vol 44, pp 181-212.

In the geologic record some of the most accurate gages of changes in sea-level are the sediment type, geometry and digenesis of carbonate shelves and platforms. This is because carbonates frequently occur at or very near sea-level and are usually less compacted than siliciclastics. World-wide changes in relative sea-level (the sum of eustatic sea-level changes, sedimentation and crustal movements) have occurred repeatedly and cyclicly through geologic time, producing characteristic responses in carbonates.

a. Relative rises in sea-level (usually caused by the cumulative effect of tectonic subsidence and eustatic rise) may result in the following:

(1) Drowned carbonate reefs or platforms. Here carbonate growth potential is exceeded by relative sea-level rise, and is characterized by shallow-water sediments, overlain by hardgrounds and/or deep-water sediments, some of which may be condensed sequences.

(2) Platforms where only the fast growing rim and patches of the interior are able to match sea-level rise while the remainder of the platform is drowned (temporarily).

(3) Platforms which keep up and maintain a flat top at sea-level and contain shallow-water sediments whose thickness at the least matches the height of the sea-level rise. If terrigenous supply is limited, prograding sheets of shelf carbonate occur (frequently capped by supratidal evaporites), with prograding shelfmargin carbonate clinoforms and turbidites. If terrigenous supply is high, the shelf carbonates encroach on deltas.

b. Relative drops in sea-level (caused by crustal uplift or by subsidence being outpaced by a eustatic drop in sea-level) cause karst and soil development over shelves sand platforms, deposition of "deep-water" evaporites in adjacent semi-enclosed basins and in open marine basins the deposition of deltaic and aeolian clastics that bypassed the shelf.

Falls are accompanied by platform-wide fresh-water digenesis. During the relative sea-level rises marine digenesis is common in the subtidal portions of the shoaling-upward carbonates, and fresh-water digenesis and dolomitization and sulphate deposition is common in their intertidal and supratidal portions.

The stratigraphic significance of these responses to relative sea-level change is that many are tied to eustatic events and so are predictable within a basin of deposition. (Authors).

169 **KERAUDREN, B., and SOREL, D.** 1987. "The Terraces of Corinth (Greece) - A Detailed Record of Eustatic Sea-Level Variations During the Last 500,000 Years," Marine Geology, Vol 77, pp 99-107.

Between Corinth and Xylokastro 20 marine terraces reflect the interaction of the northern Pelponnese uplift an the global eustative sea-level fluctuations during the last 500,000 years. Correlation of the terraces with oxygen-isotope records in deep-sea cores allowed accurate dating of these fossilized transgressive shorelines. Curves of altitude versus age have been plotted; they show a regular decrease of the uplift rate and a frequent return of the sea-level very close to the present-day one, not only during the interglacial periods (5, 7, 9, 11, 13) but also during glacial periods (3.1, 3.3, 6.8); the alternative would be to suppose very complicated and highly improbable vertical movements of the substratum to explain the regularity of the curves. The rhythm of these high sea-levels is around 20-30 ka, since at least 330,000 years ago. (Author).

170 **KNEBEL, H. J.** 1986. "Holocene Depositional History of a Large Glaciated Estuary, Penobscot Bay, Maine," Marine Geology, Vol 73, pp 215-236.

Data from seismic-reflection profiles, sidescan sonar images, and sediment samples reveal the Holocene depositional history of the large (1100 km^2) glaciated Penobscot Bay estuary of coastal Maine. Previous work has shown that the late Wisconsinan ice sheet retreated from the three main passages of the bay between 12,700 and 13,500 years ago and was accompanied by a marine transgression during which ice and sea were in contact. Isostatic recovery of the crust caused the bay to emerge during the immediate

postglacial period, and relative sea-level fell to at least -40 m sometime between 9000 and 11,500 years ago.

During lowered sea-level, the ancestral Penobscot River flowed across the subaerially exposed head of the bay and debouched into Middle Passage. Organic-matter-rich mud from the river was deposited rapidly in remnant, glacially scoured depressions in the lower reaches of Middle and West Passages behind a shallow ($\leq$20 m water depth) bedrock sill across the bay mouth. East Passage was isolated from the rest of the bay system and received only small amounts of locally derived fine-grained sediments.

During the Holocene transgression that accompanied the eustatic rise of sea-level, the locus of sedimentation shifted to the head of the bay. Here, heterogeneous fluvial deposits filled the ancestral valley of the Penobscot River as base level rose, and the migrating surf zone created a gently dipping erosional unconformity, marked by a thin (<2 m) lag deposit of coarse sand and gravel. As sea-level continued to rise, a thin ($\leq$9 m) layer of acoustically transparent muddy sediments accumulated over a shallow platform in the eastern half of the bay head. Graded sediments within this stratum began to accumulate early in the transgression, and they record both the decrease in energy conditions and the waning influence of the Penobscot River at the head of the bay. In contrast, relatively thick (up to 25 m) silty clays accumulated within a subbottom trough in the western half of the bay head. This deposit apparently developed late in the transgression after sea-level had reached -20 m and after the westward transport of fine-grained sediments from the Penobscot River had been established.

During and since the late Holocene transgression of sea-level, waves and currents have eroded, reworked, and redistributed Holocene sediments: (1) atop the shallow margins; (2) within constricted channels; (3) around topographic highs; and (4) over the shallow bedrock sill at the bay mouth.

The variable distribution, characteristics, and thickness (0 to more than 30 m) of Holocene deposits in Penobscot Bay primarily reflect: (1) the irregular glacially eroded bedrock topography beneath the bay; (2) the paleogeography of the bay during the sea-level lowstand; (3) the postglacial location of the ancestral Penobscot River; and (4) the wave and current regime during and since the Holocene sea-level transgression. (Author).

171 **KOLLA, V., and MACURDA, D. B., JR.** "Sea-Level Changes and Timing of Turbidity-Current Events in Deep-sea Fan Systems," <u>Sea-Level Changes: An Integerated Approach</u>, Special Publication No.42, Society of Economic Paleontologists and Mineralogists, Houston, TX, pp 381-392.

Although lowstands of sea-level greatly favor the development of deep-sea fan systems, the timing and type of turbidite events in these systems may depend not only on the sea-level changes but also on the nature of available sediments, tectonic setting, size, and gradients of the basins. Thus, in basins with steep gradients, located on continental or transitional crust or along active margins close to sedimentary sources that could supply coarse-grained sediments, unchannelled turbidite sand lobes and channel levee complexes might have been deposited during sea-level rises in these basins. In contrast, large fan systems, such as the Indus Fan, located off passive margins in oceanic basins with flat gradients, distant sedimentary sources, and a predominantly fine-grained sediment supply have channel-attached lobes

and channel levee, overbank complexes that were probable deposited during lowstands and to some extent during highstands of sea-level. (Author).

172 KOMAR, P. D. 1986. "The 1982-83 El Niño and Erosion on the Coast of Oregon," Shore and Beach, Vol 54, No. 2, pp 3-12.

The 1982-83 El Niño produced considerable erosion along the coast of Oregon as well as in southern California. The main contributing factors were exceptionally high sea-levels, storms which generated unusually-intense wave conditions, and the northward transport of sand along Oregon beaches. This northward movement of sand was caused by the southward displacement of the storm paths during the El Niño, and is unusual for the Oregon beaches where near-zero net littoral sand transports normally prevail. This northward sand movement was particularly important in governing the locations of beach erosion, being greatest to the north sides of headlands while sand accumulated to their south sides (the headlands acting much like groins). Particularly severe erosion has occurred on Alsea Spit where the northward sand transport deflected the inlet, erosion that still continues in direct consequence of the 1982-83 El Niño even though three years have passed.

It is unclear as to the extent of the role played by previous El Niños in Oregon-coast erosion. The 1972-73 and 1976 erosion episodes on Siletz Spit occurred during El Niños, and the high storm-wave energies important to that erosion were likely associated with the El Niños. On the other hand, there was no accompanying northward sand transport, rip-current embayments instead playing a major role in focusing the erosion. From this it appears that El Niños can be a factor in causing Oregon coast erosion, principally by the higher wave energies and perhaps increased sea-levels that accompany this phenomenon. But it is also clear that the 1982-83 El Niño was a highly exceptional event, and the erosion response to more typical El Niños will not be nearly so great as experienced during this past occurrence. (Conclusions).

173 KOMAR, P. D., and ENFIELD, D. B. 1987. "Short-Term Sea-Level Changes and Coastal Erosion," Nummedal, D., Pilkey, O.H., and Howard, J.D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 17-28.

Investigations of the role of sea-level in producing coastal erosion have focused mainly on the long-term rise due to melting of glaciers and thermal expansion of sea water. There are, however, additional shorter term changes in the local sea-level produced by a variety of ocean processes. Variations in the coastal currents, for example, can alter the water level at the shoreline due to the geostrophic balance between the current and the offshore sea-surface slope. Other factors which may alter local sea-level include changes in atmospheric pressure, winds blowing either in the longshore or cross-shore directions, and the occurrence of upwelling. Because the inclined continental shelf and slope act as a wave guide, the fluctuations often become trapped and propagate over longshore distances beyond where they are actually generated. In that many of these processes are typically seasonal, the responding sea-level also has a pronounced seasonal cycle, but

frequently there can be significant fluctuations at periodicities of several days to a few weeks. The magnitudes of such changes vary considerably with coastal location but are typically on the order of 10 to 30 cm, achieving a maximum of about 100 cm in the Bay of Bengal.

The occurrence of an El Niño in the equatorial Pacific is known to have considerable impact on the erosion of the coasts of California and Oregon. This occurs because associated with an El Niño are shifts in the storm paths and at temporary rise in sea-level. An El Niño is a breakdown of the normal equatorial wind and current patterns. This breakdown releases water which is normally set up in the western Pacific by the trade winds. The release creates a "wave" of sea-level rise, which first propagates eastward along the equator and then poleward along the eastern ocean margin. Such "waves" have been measured in the tide records of the western United States, amounting to some 20 to 60 cm and lasting for several months. Such transient sea-level changes have likely played an important role in coastal erosion. (Authors).

174 KOMINZ, M. A. 1984. "Oceanic Ridge Volumes and Sea-level Change - An Error Analysis," American Association of Petroleum Geologists, Memoir 36, pp 109-127.

Sea-level fluctuations due to changing mid-ocean ridge volumes have been calculated for the last 80 million years in 5-million year intervals. An analysis of the errors involved in this set of calculations includes: the effect of omitting calculations for crust more than 70-million year older than the ridge crest at any given time; inaccurate estimates of stage poles and ridge lengths; subducted ridges for which only a remnant triple junction remains; completely subducted ridges; and uncertainty in absolute dating of magnetic anomalies. The maximum possible sea-level 80 million years ago was 365 m (1,198 ft); the minimum was 45 m (148 ft) with a most probable height of about 230 m (755 ft) above present sea-level. A decrease in spreading rates since the Late Cretaceous was the primary cause of a volume decrease in mid-ocean ridges. (Modified Abstract).

175 KOPEC, R. J. 1971. "Global Climate Change and the Impact of a Maximum Sea-Level on Coastal Settlement," Journal of Geography, pp 541-550.

In the past decade, scientists have become increasingly concerned with man's pollution of the atmosphere and his inadvertent ability to effect change in climate at macro scales. The nature of such change is not yet known, but in this article, the premise that continued atmospheric pollution will promote higher air temperatures and ultimately coastal flooding through melting of all solid water forms, is accepted as inevitable. The author speculates on the probability of such an event and cartographically analyzes the possible extent of change in continental shapes and sizes, as well as the impact of world inundation on population densities and distributions. Projecting to 2050 A.D. as the earliest possible date for the maximization of this occurrence, it is expected that the expanding oceans will have reduced continental surfaces by approximately 17%, and roughly 19% of the population of the mid-21st century will have been relocated. (Author).

176 **KOROKII, A. M.** 1985. "Quaternary Sea-Level Fluctuations on the North Western Shelf of the Japan Sea," Journal of Coastal Research, Vol 1, No. 13, pp 293-298.

Paleogeographic reconstructions for the northwestern margin of the Japan Sea suggest that the 2 to 4-m fall of sea-level below present datum coincides with cold transitions between the Atlantic-Subboreal and Subboreal/Subatlantic episodes. Quaternary oscillations of the Japan Sea, which were glacio-eustatic in nature, resulted in the formation of lower marine and lagoonal terraces that were separated from one another by well-defined erosional features. Late Pleistocene - Holocene transgressions had greater impact on the geomorphic and sedimentary framework than did tectonic processes which occurred throughout these glacio-eustatic oscillations. The lack of marine terraces above the highest levels of the Quaternary transgressions (8 to 10 m above MSL) indicates a relatively stable or slowly subsiding northwestern shelf of the Japan Sea during the Pleistocene. Geological, geophysical, geomorphological, and absolute dating of marine deposits permitted division of a well-known marine bench previously believed to have resulted from the Riss-Wurm (Kazantsevo) transgression. This nearly equidimensional bench level is now recognized as two separate terraces, each corresponding to a Riss-Wurm transgression. (Author).

177 **KRAFT, J. C.** 1986. "Holocene Epoch Coastal Geomorphologies Based on Local Relative Sea-Level Data and Stratigraphic Interpretations of Paralic Sediments," Journal of Coastal Research, Special Issue No. 1, pp 53-59.

The paralic sediments of Delaware's Atlantic coast and estuary include a continuous depositional record of Holocene sediments from 11,000 years before present (BP). These sediments were deposited in landward migrating environments of the Holocene marine transgression superimposed and eroding into a trellis-like topography of the ancestral Delaware River (circa 15,000). Tidal waters fringed with salt marsh sediments first intruded into the inner shelf area 12,000 to 14,000 BP. As sea-level rose, the tributary valleys were inundated by tidal waters beginning 10,000 to 11,000 BP at 30 m below sea-level. These tidal marshes extended along the ancestral drainage system up to 200 kilometers inland from the projected early Holocene Atlantic shoreline.

By 7,000 BP, a lagoon-barrier coastal system had developed on the adjacent Atlantic coastal inner shelf area. This system has migrated landward by shoreface erosion and upward by rise in relative sea-level to its present coastal position. In the lagoon, barrier, and estuarine marsh areas one can drill through and study stratigraphic sequences comprised of sediments deposited landward of and including the barrier island and barrier spit system. From this stratigraphic record, one can determine the orderly and systematic transgression landward of the coastal sedimentary environments. Their sedimentary lithosomes may be observed in stratigraphic continuity from present depositional areas into the subsurface under the coastal barriers and along the estuarine shoreline. Large numbers of radiocarbon dates were used to determine the time of depositional and relative stratigraphic positions of the coastal lithosomes. Basal salt marsh peats were used to establish a local relative sea-level curve. The question remains as to whether or not sea-level rose to its present position in a smooth, continuous but ever decreasing rate

of rise or in a fluctuating manner as suggested by the vertical spread of radiocarbon dates from salt marsh sediments. Thus, a great detail of stratigraphic control with precise timing was established. From this, the nature of transgressive stratigraphic sequences was used to interpret paleogeographies of this Holocene Epoch with potential projections of future coastal morphologies. (Author).

178 **KRAFT, J. C., CHRZATOWSKI, M. J., BELKNAP D. F., TOSCANO, M. A., FLETCHER, C. H. III.** 1987. "The Transgressive Barrier-Lagoon Coast of Delaware, Morphostratigraphy Sedimentary Sequences and Responses to Relative Rise in Sea-Level," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 129-144.

Transgressive barriers of the embayed Atlantic and Gulf coast are generally similar in overall form, processes, and landward migration in response to relative sea-level rise, but they vary greatly in potential sources and volume of sand supply. Delaware's transgressive barriers vary in thickness from 25 m to less than 5 m; dunes may rise to 20 m above sea-level, whereas barrier-spit and inlet sand reach depths of 10-18 m below sea-level. Widths vary between 0 m at eroding headlands and 4-6 km near tidal delta and spit complexes.

A complete Holocene paralic sequence for Delaware includes a basal sand and/or gravel overlain by marsh, lagoon, and barrier lithosomes. Shoreface erosion, as the barrier lithosome moves landward, occurs to an average depth of 10 m, with about 50% of eroded sediment derived from Holocene and Pleistocene lagoonal mud outcrops. Since the suspended material is carried out of the shoreface, its removal requires a re-evaluation of the volumetric model commonly inferred from the Bruun mechanism. Also, the third dimension of longshore transport of coarse material needs to be considered.

As transgression continues, the ravinement surface exposes lagoonal sediments, marsh mud, irregularly shaped basal remnants of the Holocene barrier lithosome, or varied Pleistocene strata. These are then blanketed by varying thicknesses of inner-shelf sand. Ultimately, the transgressive barrier and associated paralic environments migrate landward to peak interglacial positions where the entire transgressive record may be preserved. A relatively complete vertical sequence of transgressive coastal lithosomes might also be preserved at the outer edge of the continental shelf at glacial sea-level minima. Thus, the optimal chance for total preservation of a transgressive coastal lithosome sequence lies at the extremes, landward at the peak interglacial when eustatic sea-level rise stops and the coastal lithosome sequences become stranded, and possible on the outer edge of the shelf as deglaciation begins and there is rapid rate of sea-level rise. (Authors).

179 **KROOPNICK, P. M.** 1985. "The Distribution of ^{13}C of ΣCO_2 in the World Oceans," Deep-Sea Research, Vol 32, No 1, pp 57-84.

Measurements of the $\delta^{13}C$ of total dissolved inorganic carbon (ΣCO_2) in the world oceans are presented. Most of the samples are from the GEOSECS

expeditions which covered the Atlantic, Pacific, and Indian oceans between 1971 and 1978. The results from 2252 samples from 107 hydrographic stations are presented as north-south vertical (depth) sections with $\delta^{13}C$ contoured at intervals of 0.1‰. The data show that the distribution at $\delta^{13}C$ is controlled mainly by the input of organically produced material and its subsequent oxidation as it falls through the water column. This covariance can be summarized by the regression equation: $\delta^{13}C = 1.5-0.0075 \cdot AOU$, where AOU represents the oxygen utilization within a water sample after leaving the surface. Other factors influencing the distribution of $\delta^{13}C$ are the dissolution of inorganic carbonate and the addition of anthropogenic CO_2 to the oceans. A complex mathematical model was employed to estimate the levels of ΣCO_2 an $\delta^{13}C$ in pre-industrial oceanic surface waters. The results suggest that the ΣCO_2 of surface waters has increased by 40 μmole kg^{-1} from a pre-industrial level of approximately 2135 μmole kg^{-1}. The $\delta^{13}C$ of the ΣCO_2 has decreased by 0.5‰ from a pre-industrial value of approximately 2.5‰. (Author).

180 **KUKLA, G., and GAVIN, J.** 1981. "Summer Ice and Carbon Dioxide," Science, Vol 214, No.4520, pp 497-503.

The extent of Antarctic pack ice in the summer, as charted from satellite imagery, decreased by 2.5 million square kilometers between 1973 and 1980. The U.S. Navy and Russian Atlases, and whaling and research ship reports from the 1930's indicate that summer ice conditions earlier in this century were heavier than the current average. Surface air temperatures along the seasonally shifting belt of melting snow between 55° and 80° N during spring and summer were higher in 1974 to 1978 than in 1934 to 1938. The observed departures in the two hemispheres qualitatively agree with the predicted impact of an increase in atmospheric carbon dioxide. However, since it is not known to what extent the changes in snow and ice cover and in temperature can be explained by the natural variability of the climate system or by other processes unrelated to carbon dioxide, a cause-and-effect relation cannot yet be established. (Summary).

181 **KYPER, T. M.** 1984. "The Impact of an Accelerated Sea-Level Rise on Coastal Works at Sea Bright, New Jersey," Unpublished Master's Thesis, Lehigh University, Bethlehem, Pennsylvania, pp 105.

The U.S. Environmental Protection Agency has developed four accelerated global sea-level rise scenarios to the year 2100: low, mid-range low, mid-range high, and high. The physical impact of the low and mid-range high scenarios on the beaches and coastal structures at Sea Bright, New Jersey, was investigated. Sea Bright occupies a six kilometer long section of the barrier island just to the south of Sandy Hook. The ocean shoreline is protected by a stone seawall and occasional pocket beaches held by groins; however, owing to a deficit in the littoral drift to the north, approximately 60 percent of the seawall is fronted by little or no beach.

The increases in erosion and flooding that would occur as sea-level rises were investigated for the two scenarios. Using the predictions of future erosion, the quantity and cost of sand necessary to maintain a design

beach with a 15.2-m berm width were investigated. Appropriate designs and costs for upgrading the seawall to survive the two scenarios are presented. Finally, the impact of no future protective works being implemented was investigated. (Author).

182 KYPER, T. N., and SORENSEN, R. M. 1985. "The Impact of Selected Sea-Level Rise Scenarios on the Beach and Coastal Structures at Sea Bright, N.J.," Proceedings of Coastal Zone '85, Fourth Symposium on Coastal and Ocean Management, pp 2645-2661.

The physical impacts of selected sea-level rise scenarios on the shoreline of Sea Bright, New Jersey, are investigated. The sea-level rise scenarios used were developed by the U.S. Environmental Protection Agency. Increases in shoreline recession and coastal flooding that would occur as sea-level rises are predicted. Using the recession predictions, the quantity of sand necessary to maintain a design beach with a specified berm width is estimated. Future seawall stability and design requirements for upgrading the existing seawall to survive the two scenarios are investigated. Finally, the impact of no future coastal engineering works being implemented at the site is discussed. This paper is a summary of portions of a thesis written by Kyper (1984). (Authors).

183 LACIS, A., HANSEN, J., LEE, P., MITCHELL, T., and LEBEDEFF, S. 1981. "Greenhouse Effect of Trace Gases, 1970-1980," Geophysical Research Letters, Vol 8, No. 10, pp 1035-1038.

Increased abundances were measured for several trace atmospheric gases in the decade 1970-1980. The equilibrium greenhouse warming for the measured increments of CH_4, chlorofluorcarbons and N_2O is between 50% and 100% of the equilibrium warming for the measured increase of atmospheric CO_2 during the same 10 years. The combined warming of CO_2 and trace gases should exceed natural global temperature variability in the 1980's and cause the global mean temperature to rise above the maximum of the late 1930's. (Authors).

184 LAMBECK, K., and NAKIBOGLU. 1984. "Recent Global Changes in Sea-Level," Geophysical Research Letters, Vol 11, No. 10, pp 959-961.

Tide gage records indicate that a global rise in sealevel has occurred over the past 80 years at a rate of about 1.5 mm year $^{-1}$. Because of the poor geographical distribution of the tide gages, this rise may be partly a consequence of a redistribution of water in the oceans without there being an increase in volume of the oceans. A principal contribution to this redistribution arises from the ongoing rebound of the crust to the melting of the Pleistocene ice sheets, a contribution that is of global significance even far from the limits of the original ice sheets. Model calculations indicate that this contribution may explain between 30 and 50% of the published estimates of the secular rise in sealevel. (Authors).

185 LEATHERMAN, S. P. 1983(a). "Barrier Dynamics and Landward Migration With Holocene Sea-Level Rise," Nature, Vol 301, No. 5899, pp 415-418.

Barrier beaches (islands and spits) have become the subject of mounting interest due to human development on these landforms. It is commonly thought that barrier beaches continuously migrate landward in response to sea-level rise, often by overwash processes, maintain mass through time, and that these processes are occurring at a rate commensurate with human (100 year) time frames. While some barriers are naturally migrating quite rapidly, other barriers decidedly are not. Here the author presents data which illustrate that many U.S. Atlantic Coast barriers are not evolving over the short term in accordance with generally accepted hypotheses and argue that the presumed norm may actually be the exception. (Author).

186 LEATHERMAN, S. P. 1983(b). "Barrier Island Evolution in Response to Sea-Level Rise: A Discussion," Journal of Sedimentary Petrology, Vol 53, No. 3, pp 1025-1033.

During sea-level rise, barrier islands are forced landward with shoreface retreat. While retreat rate is dependent upon the balance between sediment supply and sea-level change, continuous migration, probably intermittent at times, as opposed to barrier overstepping, is clearly favored for low coastal plain barriers. Barrier drowning and subsequent surf-zone skipping are theoretically possible, but evidence to date from the New York shelf is not convincing. Barrier islands along the U.S. Atlantic and Gulf Coasts can be expected to migrate continuously landward with sea-level rise. Exhumation of pre-Holocene or partially consolidated sediments on the shelf surface with transgression can minimize but not prohibit barrier retreat. (Summary).

187 LEATHERMAN, S. P. 1983(c). "Geomorphic Effects of Projected Sea-Level Rise: A Case Study of Galveston Bay, Texas," Proceedings of Coastal Zone '83, Third Symposium on Coastal and Ocean Management, Vol III, pp 2890-2901.

This paper describes a study of the geomorphic effects of projected sea-level rise on low-lying coastal landforms along southeast Galveston Bay, Texas. The area selected for this pilot study, a portion of the Gulf coastal plain, is quite low and gently slopes seaward. Therefore, a slight vertical rise in sea-level results in significant horizontal displacement of the shoreline and storm surge envelope. Other selection criteria included the following: microtidal environment, major Gulf Coast estuary, highly developed centers at Texas City and north Galveston Island, availability of the National Weather Service storm surge model (SLOSH), and information on historical erosional trends and subsidence data.

Three sea-level rise scenarios were generated by the Environmental Protection Agency (EPA); nine rise/year combinations were selected from the projected sea-level rise curves. Table 1 represents the algebraic sum of the projected sea-level rise and subsidence. The table indicates, for example, without an accelerated rise in sea-level (i.e., the baseline scenario), by

2025 sea-level will have risen by 13.7 cm (0.5 ft). In the medium sea-level rise scenario, sea-level will have risen by 48.4 cm (1.6 ft) in 2025. Although subsidence has historically been a major problem in Texas City, the estimated rate of future subsidence for this area is insignificant, with Galveston Island being essentially stable (Thompson, 1982).

Coastal modifications are evaluated for a range of projected sea-level rates (baseline, low, medium, and high) at particular time periods (2025 and 2075). The objective is to determine coastal change in response to various assumed sea-level increases by these particular dates. Two categories of physical responses, shoreline changes and changes in storm surge levels, are addressed. (Modified Abstract).

188 **LEATHERMAN, S. P.** 1986. "Shoreline Response to Sea-Level Rise: Ocean City, Maryland," Proceedings of Iceland Coastal and River Symposium, Reykjavik, Iceland, pp 67-276.

This paper describes the geomorphic effects of projected sea-level rise on Ocean City, a low-lying landform along the Atlantic Coast of Maryland. Coastal modifications are evaluated for a range of projected sea-level rise rates (baseline, mid-low, and mid-high) at particular time periods (2025, 2050, and 2075). The objective is to determine the shoreline change in response to these assumed sea-level increases by particular dates.

Coastal zones are inherently dynamic environments, being characterized by differing geomorphic processes and coastline configurations. To account for this wide variability in site and process, this study has combined analyses of historical trends and empirical approaches to project changes along Ocean City associated with the EPA sea-level rise scenarios. Former shoreline positions portrayed on historical maps, once digitized and transformed by a sophisticated shoreline mapping program (Metric Mapping; Leatherman, 1983a), form the basis for projecting potential shoreline excursion rates as a result of sea-level rise. These extrapolated rates can then be assessed in light of possible consequences that human modification may have on future trends. (Author).

189 **LEATHERMAN, S. P., and GAUNT, C. H.** 1989. "National Assessment of Beach Nourishment Requirements Associated with Accelerated Sea-Level Rise," Proceedings of Coastal Zone '89, Vol 2, 1978.

A significant portion of the United States' population lives within the coastal zone, where many buildings and facilities are located at elevations less than ten ft above sea-level. These structures are presently vulnerable to storm damage, a hazard that may grow more severe as greenhouse-induced global warming is expected to cause unprecedented rates of sea-level rise in the future. Despite those potential hazards, the coastal population is burgeoning. Beachfront property is some of the most valuable real estate in the country, often exceeding $10,000 per linear ft of shoreline along the U.S. mid-Atlantic coast. A lull in hurricane activity in this area since the 1960's has lead to a false sense of security and spurred this tremendous investment in coastal property. Although most coastal areas have been spared

from severe storms, beaches are still retreating landward in response to slowly rising sea-level. Best estimates are that 90% of the U.S. sandy beaches are presently eroding. The predicted accelerated sea-level rise will increase erosion rates and associated problems.

This research provides a preliminary estimate of the sand volumes and costs to nourish all existing and potential recreational oceanic beaches in the U.S. given various sea-level rise scenarios. The guiding concept of beach nourishment is to place enough sand on the beach to maintain stable (non-retreating) conditions with rising sea-levels. This study evaluates the quantity of sand required to "hold the line" using six sea-level rise scenarios, assuming a worse-case scenario of approximately ten ft of rise by the year 2100. The potential costs of these nourishment projects were estimated using the best available data for existing beach nourishment projects. (Modified Introduction).

190 **LISITZIN, E.** 1961. "The Contemporary Knowledge of the Causes of the Seasonal Cycle of Sea-Level in the Oceans," International Hydrographic Review, Vol 38, No. 1, pp 141-153.

Lisitzin discusses the regional and local causes of the seasonal variation in sea-level. Case studies were used to document the effects of seasonal changes along three major types of coastlines: (1) the southeastern coast of the United States, (2) the northeastern coast of the United States, and (3) the coastal areas and islands in the Pacific Ocean. (Gorman).

191 **LISITZIN, E.** 1974. Sea-Level Changes, Elsevier, Amsterdam, New York, pp 286.

The author discusses the factors that affect sea-level changes such as; astronomical tides, meteorologic effects, seasonal variation, structural changes, seiches, and tsunamis. Lisitzin also examines sea-level statistics used for coastal protection. Emphasis of sea-level variations were based on from the Baltic Sea where tidal changes are minimal. (Gorman).

192 **LISITZIN, E., and PATTULLO, J. G.** 1961. "The Principal Factors Influencing the Seasonal Oscillation of Sea-Level," Journal of Geophysical Research, Vol 66, No. 3, pp 845-853.

From the results of the tide gage data recorded during the IGY, it is shown that the seasonal variation of sea-level is mainly isostatic, at least in most oceanic areas of the Pacific. In low and subtropical latitudes the 'steric' term is predominant; in higher latitudes variation of air pressure is the more important factor. The boundary between the two zones runs approximately along the latitude of 40°-45° N. (Authors).

193 LISLE, L. D. 1982. "Annotated Bibliography of Sea-Level Changes Along the Atlantic and Gulf Coasts of North America," Shore and Beach, Vol 50, No.3, pp 24-33.

The author in this bibliography includes English language references mostly published during the last 20 years up to March 1982. Lisle emphasizes that his is a "selected" bibliography on reports with application to shore zone processes along the Atlantic and gulf coasts of North America. This annotated bibliography has been divided into seven categories:

(1) General information on sea-level changes with reference to the US Atlantic coast.
(2) Geological evidence of sea-level change, references to pre-Pleistocene fluctuations.
(3) Atlantic coast of North America, references of an extended nature.
(4) North Atlantic coast, evidence from north of New Jersey.
(5) Mid-Atlantic coast, evidence from New Jersey through South Carolina.
(6) South Atlantic coast, Georgia, Florida, and the Bahamas.
(7) Gulf coast.
(8) McCloy's bibliography of 1964, references to the North American east and gulf coasts. (Gorman).

194 LISLE, L. D. 1989. United States Sea-Level Changes, pp 277-286.

Changing sea-level is currently a topic of great interest. Coastal areas have experienced erosion, caused in large part by rising sea-level, that has destroyed private homes, commercial property and public lands. Perhaps the most extreme predictions on rising sea-level problems have been made in recent EPA publications (Hoffman et al., 1983; Barth and Titus, 1984). According to these investigators sea-level rise will be accelerated over the next century as the level of anthropogenic CO_2 increases in our atmosphere. This will further acerbate an already serious problem along the U.S. developed coastlines. This paper examines geological, historical, and current trends of sea-level change along the United States coastlines with emphasis on the Atlantic Coast, and considers some underlying reasons for these trends. (Modified Introduction).

195 LOUTIT, T. S., HARDENBOL, J., VAIL, P. R., BAUM, G. R. 1988. "Condensed Section: The Key to Age Determination and Correlation of Continental Margin Sequences," Wilgus, C.K., Hastings, B.S., Kendall, C.G., Posamentier, H.W., Ross, C.A., and Van Wagoner, J.C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 183-215.

Condensed sections play a fundamental role in stratigraphic correlation, both regionally and globally. Condensed sections are thin marine stratigraphic units consisting of pelagic to hemipelagic sediments characterized by very low-sedimentation rates. Areally, they are most extensive at the time of maximum regional transgression of the shoreline.

Condensed sections are associated commonly with apparent marine hiatuses and often occur as thin, but continuous, zones of burrowed, slightly lithified beds (omission surfaces)or as marine hardgrounds. In addition, condensed sections may be characterized by abundant and diverse planktonic and benthic microfossil assemblages, authigenic minerals (such as glauconite, phosphorite, and siderite), organic matter, and bentonites and may possess greater concentrations of platinum elements such as iridium. Condensed sections are important because they tie the temporal stratigraphic framework provided by open-ocean microfossil zonations to the physical stratigraphy provided by depositional sequences in shallower, more landward sections. Condensed sections represent a physical stratigraphic link between shallow- and deep-water sections and are recognized by the analysis of seismic, well-log, and outcrop data. Within each depositional sequence, condensed sections are best recognized and utilized within an area from the shelf/slope break landward to the distal edge of inner neritic-sand deposition. Where sedimentation rates are generally low, as in the deep oceanic, a number of condensed sections may coalesce to form a composite condensed section. Data from detailed analyses of continental-margin condensed sections are presented to illustrate the nature and importance of condensed sections for dating and correlating continental-margin sequences and reconstructing ancient depositional environments. (Authors).

196 **LOUTIT, T. S., and KENNETT, J. P.** 1981. "New Zealand and Australian Cenozoic Sedimentary Cycles and Global Sea-Level Changes," American Association of Petroleum Geologists, Bulletin 65, No. 9, pp 1586-1601.

A global sea-level history determined by Vail et al consists of 23 sea-level cycles between the base of the Cenozoic and the Pliocene-Pleistocene boundary (65 to 1.8 Ma). We have examined the relation between this global sea-level history and the New Zealand and Australian continental margin shallow-marine sedimentary record.

Sedimentary cycles in the Australian Cenozoic marginal-marine sequences are bounded by unconformities of various durations. The tectonic stability and aridity of the western and southwestern margin of Australia during the Cenozoic produced a sedimentary record dominated by hiatuses. This contrasts with the relatively complete sequences of the tectonically more active south-eastern marginal basins. The four major sedimentary cycles in the Australian Cenozoic (Paleocene to early Eocene; middle to late Eocene; latest Oligocene to late middle Miocene; and latest Miocene to Quaternary) correlate with the supercycles Ta, Tb, Tc, Td, and Te of Vail et al.

In New Zealand most of the Cenozoic stages represent classic sedimentary cycles bounded by unconformities or correlative conformities formed as a result of large, rapid eustatic sea-level changes. The marine Tertiary sequence in New Zealand consists of 23 stages. Of the 18 stage boundaries between the end of the Paleocene (53 Ma) and the end of the Miocene (5 Ma), 16 appear to correlate with the boundaries of eustatic sea-level cycles.

Eustatic sea-level lowstands are well recorded (as unconformities) in New Zealand as a result of its unique tectonic setting during the Cenozoic. For most of the early Cenozoic until the middle Oligocene (~30 Ma) New Zealand was generally subsiding. After the middle Oligocene this region began to be uplifted as the Pacific-Australian plate boundary migrated onto New Zealand,

climaxing in the latest Cenozoic (late Pliocene-Quaternary), thus exposing a nearly complete sequence of marine Cenozoic strata well suited for the study of sedimentary cycles.

Uncomformities, which form as a result of eustatic sea-level changes, represent a very useful correlation tool, especially on continental margins with a sufficiently high terrigenous sediment supply, and can be used to supplement paleontologic correlations. Their ultimate usefulness for correlation depends on the rapidity of the sea-level changes or the speed at which sedimentary facies change in response to sea-level changes. If sea-level changes rapidly (10 m/1,000 years), stratigraphic resolution will be high ($\pm 10^5$ years) but resolution decreases as the speed of sea-level change decreases. Unconformities may well prove to be a vital tool linking the classic land-based sections around the world with deep-sea sections.(Authors).

197 **LUTJEHARMS, J. R. E., and ALHEIT, M. M.** 1982. "Long-Term Sea-Level Measurements, A Global Catalogue," National Technical Information Service Technical Report Number CSIR/TR/SEA-8210, pp 110.

This catalogue comprises a listing of all available sea-level measurements in the world ocean for which records for more than five years duration exist. The information includes the duration of such measurements, where they were made, and the source of such data. The purpose of the catalogue is to give an overview of the global distribution of long-term sea-level measurements, relative to the major ocean currents, in order to facilitate deciding on the location of new tide gage installations for the purpose of studying long-term climatic changes. (National Technical Information Service citation).

198 **LUTERNAUER, J. L., CLAGUE, J. J., CONWAY, K. W., BARRIE, J. V., BLAISE, B., MATHEWES, R. W.** 1989. "Late Pleistocene Terrestrial Deposits on the Continental Shelf of Western Canada: Evidence for Rapid Sea-Level Change at the End of the Last Glaciation," Geology, Vol 17, pp 357-360.

A paleosol with in situ rooted plant remains has been found in a core at a water depth of 95 m on the central continental shelf of British Columbia. Fluvial sediments associated with the paleosol are sharply overlain by lagoonal or shallow pond sediment; these, in turn, are overlain by shallow-marine sediments. Radiocarbon dates on wood fragments and root recovered from the cored sediments indicate that relative sea-level was at least 95 m lower 10,500 year B.P. and that the core site was rapidly transgressed by the sea shortly thereafter. This rapid transgression was contemporaneous with an equally rapid regression at the heads of fiords on the British Columbia mainland to the east. The two are probably genetically linked and a result of late Pleistocene deglaciation and the migration and collapse of a glacial forebulge. Our evidence indicates that large areas of the British Columbia continental shelf were subaerially exposed 11-10 ka. This may have facilitated the southward migration of early humans from Beringia into mid-continental North America at the end of the Pleistocene. (Authors).

199 LYLES, S. D., HICKMAN, L. E., JR. and DEBAUGH, H. A., JR. 1988. Sea-Level Variations for the United States, 1855-1986, National Oceanic and Atmospheric Administration, Rockville, Maryland, pp 182.

Relative apparent secular sea-level trends, their standard errors, and annual variabilities are computed for 78 United States long-term control stations. The computations and for the common series length, 1950 through 1986. Graphs of both monthly and yearly mean sea-level are depicted for the individual stations. Monthly and yearly mean sea-level data are tabulated for the entire length of series at the 78 stations. (Author).

200 MACINTYE, I. G., PILKEY, O. H., STUCKENRATH, R. 1978. "Relict Oysters on the United States Atlantic Continental Shelf: A Reconsideration of Their Usefulness in Understanding Late Quaternary Sea-Level History," Geological Society of America, Bulletin 89, pp 277-282.

Relict oyster shells are thought to be unreliable references for reconstructing sea-level history owing to interrelationships between their age and present depth of occurrence off North Carolina. Radiocarbon dates were obtained from 44 relict oyster shells of Crassostrea virginica (Gmelin) collected within a relatively narrow area of the continental shelf from north of Cape Hatteras to Cape Fear (less than 40,000 km^2) in depths to 60 m. Data indicate significant post depositional and landward transport of these shells, calling into question some previous interpretations of sea-level history that were based partly on the dating of relict oyster shells and other unreliable relict shoreline deposits. (Authors).

201 MALATESTA, A., and ZARLENGA, F. 1988. "Evidence of Middle Pleistocene Marine Transgressions Along the Mediterranean Coast," Palaeogeography, Palaeoclimatology, Palaeoecology, Vol 88, No. 2-4, pp 311-315.

Typical Middle Pleistocene sequences outcropping along French and Italian coasts are described. Age determination from palaeolithic industries and absolute dating methods correspond to oxygen isotope stages 9 and 11. Evidence of the same transgressive cycles are also indicated in other Mediterranean districts. (Authors).

202 MANABE, S., and BRYAN, K., JR. 1985. "CO_2 -Induced Change in a Coupled Ocean-Atmosphere Model and Its Paleoclimatic Implications," Journal of Geophysical Research, Vol 90, No. C6, pp 11689-11707.

The climatic effects of very large changes of CO_2 concentration in the atmosphere are explored using a general circulation model of the coupled ocean-atmosphere system. As a simplification the model has an annual mean isolation and a highly idealized geography. A series of climatic equilibria are obtained for cases with 1/2, $1/\sqrt{2}$,1,2,4, and 8 times the present CO_2

concentration in the atmosphere. The results from these six numerical experiments indicate the climatic signatures of large CO_2 changes in the atmosphere and in the abyssal and surface waters of the ocean. As the CO_2 concentration in the model atmosphere increased from 1 to 8 times the normal value, the meridional gradient of surface air temperature decreased, while that of upper tropospheric temperature increased in agreement with the results of earlier CO_2 climate sensitivity studies. However, the intensity and latitudinal placement of the atmospheric jet hardly changed. Despite the reduction of meridional temperature gradient, the meridional density gradient of water at the ocean surface changed little because of the increase of thermal expansion coefficient of seawater with increasing temperature. Thus the intensity of thermohaline circulation in the ocean model does not diminish as expected in the range from 1 to 8 times the normal atmospheric CO_2 concentration. As was shown in an earlier study, the CO_2-induced changes in the deep sea follow the change of sea surface temperature in high latitudes and thus are much larger than the globally averaged changes of sea surface temperature. The model predicts that the area mean rates of precipitation, evaporation, and runoff increase with increasing CO_2 concentration in the atmosphere. The latitudes of the arid zone and the high surface pressure belt in the subtropics are almost constant in the entire range of 1-8 times normal CO_2. In general, the climatic signature obtained from the model appears to be consistent with a CO_2 hypothesis for the climatic changes in the Cenozoic with the following exception: the tropical sea surface temperature in the model has a small but significant increase with increasing atmospheric CO_2 concentration, while tropical sea surface temperature as deduced from the isotopic record appears to have no systematic trend during the Tertiary. It is found that the climate corresponding to one-half normal CO_2 is markedly different from the normal and high CO_2 gases. Sea ice extends to middle latitudes, and the thermohaline circulation in the model ocean loses its intensity and is largely confined to an area between the sea ice margin and the equator. The poleward heat transport by ocean currents is very small in high latitudes, markedly reducing the surface air temperature there. It is suggested that a similar process, which enhances the positive albedo feedback effect of sea ice, played a key role in reducing surface air temperatures over the North Atlantic during the last glacial maximum. (Authors).

203 MARANTO, G. 1986. "Are We Close to the Road's End?" Discovery, January, 1986, pp 28-50.

The author interviewed a half-dozen leading climatologists and scientists on the current research and theories on how CO_2 may affect the earth. Climatic consequences such as sea-level rise, greenhouse effect, and glacial melting are also discussed. (Gorman).

204 MARTIN, L., SUGUIO, K., and FLEXOR, J. M. 1988. "High Pleistocene Sea-Levels Along the Brazilian Coast," Palaeogeography, Paleoclimatology, Palaeoecology, Vol 68, No. 2-4, pp 231-239.

The high sea-level, corresponding to the last Pleistocene interglacial stage, left the most important records represented by extensive beach-ridge plains along the central and southern coasts of Brazil. During the maximum level, which was dated at 123,000 year BP by coral samples, the relative sea-level was situated 8±2 m above present level. Four generations of Quaternary marine sandy deposits have been described in southern Brazil (State of Rio Grande do Sul), where they are known as Barrier III, with a height of about 123,000 year BP. The Barrier II, about 13-15 m high, and the Barrier I, about 20-25 m high, situated at inner positions in relation to the previous ones, have been formed during high sea-levels older than 123,000 year. (English Summary)

205 MASUDA, F. 1986. "Vail Sea-Level Curve Records the Ages of Plate Motion Change," pp 64-67.

"Vail sea-level curve" representing the relative change of global sea-level during the Phanerozoic was presented by Vail et al. (1977). This curve has been widely accepted and used by many investigators. It is generally agreed that the changes of "Vail sea-level curve" are caused by the change of the average depth of the ocean floor and moreover, sea-level changes can be induced by volume changes in world oceanic spreading ridge system.

In this paper, the author presents a good age correlation between the changes of plate motion and rapid falls in "Vail sea-level curve". The correspondence suggests that the rapid falls were caused by the change of plate motion. (Modified Introduction).

206 MAUL, G. A. 1986. "Linear Correlations Between Florida Current Volume Transport and Surface Speed with Miami Sea-Level and Weather During 1964-1970," Geophysical Journal, Royal Astronomical Society, pp 55-66.

The 1964-70 Florida Current data of Niiler & Richardson are examined for linear correlation with observed sea-level and weather, because their data provide an independent test of similar correlations reported in Maul et al. Seventy-five values of directly measured volume transport and 67 values of surface speed from Niiler & Richardson's unevenly spaced data are correlated with available daily mean values of Miami Beach sea-level, Bimini sea-level, Bimini - Miami Beach sea-level difference, and Miami weather (barometric pressure, air temperature, and north and east components of wind speed). Statistical frequency distribution of transport and of surface speed suggest variability that is not dominated by annual and/or semiannual cycles. Volume transport is most highly correlated with Bimini minus Miami Beach sea-level. Including certain weather variables results in statistically significant improvements in linear multivariate modelling of transport and surface speed

from sea-level; the standard errors are ± 2.6 sverdrup and ± 10 cm s^{-1} respectively. Linear correlation coefficients and multivariate regression parameters from Niiler & Richardson's data are in agreement with those from Maul et al., except that the standard error of estimating volume transport from sea-level is smaller in Maul et al., apparently because of smaller errors in the direct measurements. (Author).

207 **MAUL, G. A., CHEW, F., BUSHNELL, M., and MAYER, D. A.** 1985. "Sea-Level Variation As An Indicator of Florida Current Volume Transport: Comparisons With Direct Measurements," Science, Vol 227, pp 304-307.

Sea-level measurements from tide gages at Miami, Florida, and Cat Cay, Bahamas, and bottom pressure measurements from a water depth of 50 m off Jupiter, Florida, and a water depth of 10 m off Memory Rock, Bahamas, were correlated with 81 concurrent direct volume transport observations in the Straits of Florida. Daily-averaged sea-level from either gage on the Bahamian side of the Straits was poorly correlated with transport. Bottom pressure off Jupiter had a linear coefficient of determination of $r^2 = 0.93$, and Miami sea-level, when adjusted for weather effects, had $r^2 = 0.74$; the standard errors of estimating transports were $\pm 1.2 \times 10^6$ and $\pm 1.9 \times 10^6$ cu m per second, respectively. A linear multivariate regression, which combined bottom pressure, weather, and the submarine cable observations between Jupiter and the Bahamas, had $r^2 = 0.94$ with a standard error of estimating transport of $\pm 1.1 \times 10^6$ cubic ms per second. These results suggest that a combination of easily obtained observations is sufficient to adequately monitor the daily volume transport fluctuations of the Florida Current. (Authors).

208 **McMANUS, D. A., and CREAGER, J. S.** 1984. "Sea-Level Data For Parts of the Bering-Chukchi Shelves of Beringia From 19,000 to 10,000 14C year B.P.," Quaternary Research, Vol 21, pp 317-325.

Sea-level changes in Beringia are especially significant because they affect the migration of land plants and animals between Asia and North America, and marine plants and animals between the Pacific and Arctic oceans. Previous studies of cores from the Bering and Chukchi shelves produced sea-level curves. Evaluation of these data suggests that nine of the radiocarbon-dated estimates of sea-level position are most reliable for the time period 19,000 to 10,000 year Before Present. The trend of these nine points is proposed as the basis for a regional sea-level curve for central Beringia. Constraints on the data must be noted, however, by anyone using them. (Authors).

209 MEADE, R. H., and EMERY, K. O. 1971. "Sea-Level As Affected By River Runoff, Eastern United States," Science, Vol 173, pp 425-428.

Variation in annual river inflow account for 7 to 21 percent of the total variation in average annual sea-level along the Atlantic and Gulf of Mexico coasts of the United States. This compares with 29 to 68 percent of the total variation that can be attributed to the secular rise of sea-level and with 10 to 50 percent of the variation that cannot be attributed to either the river inflow or the secular rise. (Authors).

210 MEHTA, A. J., and CUSHMAN, R. M. 1989. Workshop on Sea-Level Rise and Coastal Processes, DOE/NBB-0086, U.S. Department of Energy, Washington, DC.

The possibility in the coming decades of a higher rate of relative sea-level rise globally is now thought to be sufficiently great to warrant serious consideration for its potential implications to civilization. With regard to shoreline response to relative rise as well as the rate of rise, questions emerge almost immediately about how the open coast and estuarine shorelines would change. Since, for example, a significant portion of the U.S. coastline is composed of loose materials including sand and muddy sediment, it is evident that simple inundation models based on existing terrestrial topography would be far from adequate in predicting shoreline configurations for any given sea-level rise scenario. Consequently, it becomes essential to examine the state-of-the-art technology to accomplish the task of prediction to a meaningful level of accuracy.

In this report, the effects of potential sea-level rise on the shoreline and shore environment were briefly examined by considering the interactions between sea-level rise and coastal processes. These interactions were reviewed, beginning with a discussion of the need to reanalyze previous estimates of eustatic sea-level rise and compaction effects in water level measurement. This was followed by considerations on coastal and estuarine tidal ranges, storm surge and water level response, and marine interaction with natural and constructed coastal features. The desirability to reexamine the well-known Bruun rule for calculating shoreline recession due to the likelihood of significant cross-shelf sediment transport was recognized. The mechanics of salt penetration in groundwater and surface water was reviewed, followed by effects of sedimentary processes in the estuaries including wetland response, particularly in the fine-grained environment. Finally, comments were included on some probable effects of sea-level rise on coastal ecosystems, since response in this case is unquestionably contingent upon hydrodynamic and sedimentary forcing. (Modified Summary).

211 MEHTA, A. J., DEAN, R. G., DALLY, W. R., and MONTAGUE, C. L. 1987. "Some Considerations on Coastal Processes Relevant to Sea-Level Rise," UFL/COEL-87/012, Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, FL, 187 pp.

The effects of potential sea-level rise on the shoreline and shore environment have been briefly examined by considering the interactions between sea-level rise and relevant coastal processes. These interactions have been reviewed beginning with a discussion of the need to reanalyze previous

estimates of eustatic sea-level rise and compaction effects in water level measurement. This is followed by considerations on sea-level effects on coastal and estuarine tidal ranges, storm surge and water level response, and interaction with natural and constructed shoreline features. The desirability to reevaluate the well known Bruun Rule for estimating shoreline recession has been noted. The mechanics of ground and surface water intrusion with reference to sea-level rise are then reviewed. This is followed by sedimentary processes in the estuaries including wetland response. Finally comments are included on some probable effects of sea-level rise on coastal ecosystems.

These interactions are complex and lead to shoreline evolution (under a sea-level rise) which is highly site-specific. Models which determine shoreline change on the basis of inundation of terrestrial topography without considering relevant coastal processes are likely to lead to erroneous shoreline scenarios, particularly where the shoreline is composed of erodible sedimentary material.

With some exceptions, present day knowledge of shoreline response to hydrodynamic forcing is inadequate for long-term quantitative pre-dictions. A series of inter-related basic and applied research issues must be addressed in the coming decades to determine shoreline response to sea-level change with an acceptable degree of confidence. (Authors).

212 MEIER, M. F. 1984. "Contribution of Small Glaciers to Global Sea-Level," Science, Vol 226, No. 4681, pp 1418-1421.

Observed long-term changes in glacier volume and hydro-meteorological mass balance models yield data on the transfer of water from glaciers, excluding those in Greenland and Antarctica, to the oceans. The average observed volume change for the period 1900 to 1961 is scaled to a global average by use of the seasonal amplitude of the mass balance. These data are used to calibrate the models to estimate the changing contribution of glaciers to sea-level for the period 1884 to 1975. Although the error band is large, these glaciers appear to account for a third to half of observed sea-level rise, approximately that fraction not explained by thermal expansion of the ocean. (Author).

213 MEISLER, H., LEAHY, P., and KNOBEL, L. L. 1985. "Effect of Eustatic Sea-Level Changes on Saltwater-Freshwater Relations in the Northern Atlantic Coastal Plain," U.S. Geological Survey Water-Supply, Paper 2255, pp 28.

This paper describes the effect of eustatic sea-level changes on the physical and chemical relations between fresh and salty ground water in the northern Atlantic Coastal Plain and adjacent Continental Shelf. A transition zone is known to be 1,000 to 2,000 ft thick and extends 60 miles off the New Jersey Coast. A finite-difference computer model was used to test the effects of eustatic sea-level fluctuations on the development of the transition zone. Geochemical studies of the ground water were also conducted on a regional level to relate the composition of ground water in the transition zone to the

composition of ground water in the transition zone to the composition of fresh ground water and seawater. (Modified Abstract).

214 MEO, M. 1989. "Climate Change Impacts on Coastal Environments: Implications for Strategic Planning," Proceedings of Coastal Zone '89, Vol 2, pp 1384.

As scientific reports continue to link trace gas emissions with changing climate, concern has grown over the near-term implications of climate change for public policy in general and strategic planning in particular. Coastal environments are especially vulnerable to "greenhouse effect" impacts such as accelerated sea-level rise, reduction of fresh water inflows, and the possible increase in the frequency of extreme storm events. Two major concerns of decision makers are to determine the timing and magnitude of different climate change impacts and to design rational strategies for responding to them. Climate change impacts on coastal environments with reference to three coastal regions including: Apalachicola Bay and estuary in northwest Florida, the Mississippi River Deltaic Plain in coastal Louisiana, and the Sacramento-San Joaquin Delta in California. (Modified Abstract).

215 MERRILL, A. S., EMERY, K. O., and RUBIN, M. 1965. "Ancient Oyster Shells on the Continental Shelf," Science, Vol 147, pp 398-400.

Shells of long-dead Crassostrea virginica are reported at 71 stations in depths of 14 to 82 ms. The depths exceed those of the estuaries where the species flourishes. Radiocarbon measurements indicate that the oysters were alive 8000 to 11,000 years ago. It is concluded that the oysters lived in lagoons or estuaries which became submerged when the sea-level rose at the end of the latest glacial epoch. (Authors).

216 MIDDLETON, J. F., and THOMPSON, K. R. 1986. "Return Periods of Extreme Sea-Levels From Short Records," Journal of Geophysical Research, Vol 91, No. C10, pp 11,707-711,716.

Extreme sea-levels usually arise from a combination of the tides (assumed here to be deterministic) and story surges (assumed stochastic). We show in this paper how tide and surge statistics derived from short (~1 year) records can be used to predict the occurrence of extremes with much longer return periods (~50 years). The method is based on an extension of the exceedance theory originally developed by Rice (1954) to study noise in electrical circuits. A comparison of predicted return periods with those obtained directly from a 50-year Markovian simulation of surge is used to validate the exceedance probability method. The method is next applied to the Canadian ports of Halifax and Victoria, which are dominated by semidiurnal and diurnal tides, respectively. To provide a stringent test of the method, just 1 year's data from each port are used to estimate the tide, surge statistics, and hence return periods. The predictions are found to compare well with the results of

a conventional (Gumbel) extremal analysis based on more than 60 years of data provided allowance is made for (1) the abnormality of the surge distribution and (2) seasonal changes of surge variance. The agreement suggests that the method may be successfully applied to other short sea-level records or indeed to any partly deterministic process where return periods are of interest. (Authors).

217 MILLER, K. G., MOUNTAIN, G. S., and TUCHOLKE, B. E. 1985. "Oligocene Glacio-Eustasy and Erosion on the Margins of the North Atlantic," Geology, Vol 13, No. 1, pp 10-13.

Oligocene foraminiferal $\delta^{18}O$ records suggest the development of ice caps (= inferred glacio-eustatic falls) at ca. 36, 31, and 25 Ma. Biostratigraphic analyses of wells from the United States east coast and Irish continental margins consistently show that upper Oligocene sediments overlie a dischronous erosional surface, underlain by lower Oligocene to Eocene strata. At the minimum, the hiatus extends between ca. 34 and 30 Ma. We speculate that erosion during a glacio-eustatic fall near the early/late Oligocene that erosion during a glacio-eustatic fall near the early/late Oligocene boundary (ca. 32-31 Ma) developed (1) an unconformity on the margins, (2) numerous canyons noted in seismic profiles from the margins of the North Atlantic, and (3) a coastal offlap event. Using $\delta^{18}O$ data, we apply a model for eustatic changes and margin response that explains the relationships of sea-level, unconformities, and coastal onlap/offlap events. (Authors).

218 MILLIMAN, J. D., and EMERY, K. O. 1968. "Sea-Levels During the Past 35,000 Years," Science, Vol 162, No. 3858, pp 1121-1123.

A sea-level curve of the past 35,000 years for the Atlantic continental shelf of the United States is based on more than 80 radiocarbon dates, 15 of which are older than 15,000 years. Materials include shallow-water mollusks, oolites, coralline algae, beachrock, and salt-marsh peat. Sea-level 30,000 to 35,000 years ago was near the present one. Subsequent glacier growth lowered sea-level to about -130 ms 16,000 years ago. Holocene transgression probably began about 14,000 years ago, and continued rapidly to about 7,000 years ago. Dates from most shelves of the world agree with this curve suggesting that it is approximately the eustatic curve for the period. (Authors).

219 MOBLEY, C. M. 1988. "Holocene Sea-Levels in Southeast Alaska: Preliminary Results," Arctic, Vol 41, No. 4, pp 261-266.

Natural raised marine deposits and archaeological sites recently discovered in SE Alaska have been measured relative to mean sea-level and radiocarbon dated. Plots of sites on Heceta and Prince of Wales islands are compared to those developed for British Columbia. Because Holocene sea-levels are a function of isostatic rebound due to removal of glacial ice, as well as global sea-level changes and tectonic activity, the implication is that

whereas Heceta Island underwent processes and magnitudes of glaciation and isostatic rebound similar to the Queen Charlotte Islands, Prince of Wales Island was subjected to a pattern of glaciation and isostatic rebound different from that of the Queen Charlotte Islands and mainland of British Columbia. (Author).

220 **MOORE, S.** 1946. "Crustal Movement in the Great Lakes Area," Geological Society of America, Bulletin 59, pp 697-710.

The crustal movement in progress at the present time has been determined at 106 points in the Great Lakes area. The entire area, except for the extreme northerly part of Lake Superior, is subsiding with respect to sea-level. The methods employed and the results obtained are discussed, but no conclusion as to the cause of the movement is reached. (Author).

221 **MORNER, N.-A.** 1973. "Eustatic Changes During the Last 300 Years," Palaeogeography, Palaeoclimatology, Palaeoecology, Vol 12, No. 1, pp 1-14.

Tide gages in rising and subsiding areas show a major change in the shore-level displacement at about A.D. 1840, caused by the onset of a rapid eustatic rise. Comparisons between information from Amsterdam, Stockholm and Warnemunde provide material for the reconstruction of the eustatic changes during the last 290 years. Relative uplift data from the Swedish west coast, corrected according to the eustatic curve established here, give the same location of the isostatic zero isobase as does the geological material for the last 7,000 years. The eustatic changes closely follow climatic changes. A rapid eustatic rise started about 1840, showed down about 1930 and ended about 1950. Knowing the eustatic factor, the isostatic (or tectonic) factor is calculated for different areas of importance in the discussion of Holocene eustatic sea-level changes. (Author).

222 **MORNER, N.-A.** 1976. "Eustasy and Geoid Changes," Journal of Geology, Vol 84, No. 2, pp 123-151.

The real ocean surface-the equipotential surface of the geoid or the geodetic sea-level-is rough and uneven and characterized by humps and depressions of several ms. The present geoid configuration cannot have remained stationary back in time. The main question is over what time units geoid changes may have played a significant role. The instability of the geoid configuration has not been considered previously. The geoid may change both horizontally (geographical dislocation of the geoid relief) and vertically (magnitudinal changes in relief). There are numerous variables (during different geological time units) that must have affected the geoid. Geoid changes must certainly have occurred during the Phanerozoic and the Late Quaternary. Holocene "eustatic" data also yield indication of geoid changes. Tide gage data and Holocene eustatic short-period fluctuations seem to indicate geoid changes even during short-period time units. Geoid changes are

related to fundamental geophysical- astronomical problems. Late Quaternary data suggest a cyclic pattern of the geoid changes that resembles the precession cycle. Holocene geoid changes--like correlated magnetic, climate, and volcanic fluctuations--seem to be caused by changes at the core/mantle interface (bumps and eddies) and coupling. Because of geoid changes, eustasy is not globally valid. (Authors).

223 **MORNER, N.-A.** 1978. "Palaeogeoid Changes and Palaeoecological Changes in Africa With Respect to Real and Apparent Palaeoclimatic Changes," Palaeoecology of Africa and the Surrounding Islands, Vol 10, Bakker and Coetzee Eds., A.A. Balkema/Rotterdam.

Paleogeoid changes affect the ocean level configuration and the geoid under the continents which may affect the ground water level. The correlation between pre-Pliocene drought and mammalian extinction levels and general sea-level regressions is explained by palaeogeoid changes instead of a palaeo-temperature changes. The ice age aridity and early Holocene humidity in Africa seem mainly or partly to be the effect of palaeogeoid changes. The late Holocene increasing aridity may be explained in terms of cyclic geoid changes. The aridity at around 115,000 BP (isotope stage 5d) may not at all correspond to a major glaciation period, which would drastically change our base for prediction of future climate. Palaeoecological variations should be analyzed with respect to the possible effect of a palaeogeoid changes in order to separate real and apparent palaeoclimatic changes. (Author).

224 **MORNER, N.-A.** 1980. "The Northwest European 'Sea-Level Laboratory' and Regional Holocene Eustasy," Palaeogeography, Palaeoclimatology, Palaeocology, Vol 29, pp 281-300.

The northwest European coasts and shelf, including rising, subsiding and semi-stable areas, can be regarded as an immense "sea-level laboratory" where the interaction between eustasy, crustal movements and local paleoenvironmental effects can be analyzed, separated and checked. Central Fennoscandia has risen by 830 m and the North Sea basin has subsided by 170 m in response to the Late Weichselian glaciation. This implies rapid horizontal motions of a low-viscosity asthenosphere. Sea-level oscillations are recorded both in uplifted and subsided areas. The Fennoscandian shorelines are uplifted and tilted, and hence separated so that they can be clearly identified and dated. Each little Postglacial transgression maximum (PTM) is represented by a morphologically identified shoreline that has been followed from some 250 km in the direction of tilting in the Kattegat region. The amplitudes of the interjacent regressions are will expressed in the stratigraphy and can be determined with great accuracy. The Kattegat sea-level spectrum offers a "eustatic test area." The eustatic curve calculated from the Kattegat data agrees in such detail with the records from other parts of northwestern Europe (e.g., northwest England, The Netherlands, northern Norway) that it must be concluded that reflects the regional eustatic changes. It is a low amplitude oscillating curve. Local paleoenvironmental effects are sometimes recorded, e.g., in relation to the climatic deterioration at the Subboreal/ Subatlantic

transition. Paleotidal changes seem to be recorded from the Atlantic coast of France. The eustatic fluctuations correlate with fluctuations in paleomagnetism and paleotemperature. This suggests a mutual origin. With the theory of paleogeoid changes, we must solve each region within itself and establish regional eustatic curves. The northwest European region provides such a solution. When similar solutions are established from other parts of the globe, the directions, amplitudes and the rates of the paleogeoid changes can be measured. (Author).

225 MORNER, N.-A. 1981. "Eustasy, Paleoglaciation and Paleoclimatology," Aufsatze, Band 70, Heft 2, pp 691-702.

Eustasy is not a direct measure of the glacial volume changes during the Late Cenozoic but largely the effect of paleogeoid changes. Neither are the oceanic oxygen isotope records a direct measure of the glacial volume changes and the glacial eustatic sea-level changes, instead they are also to a significant degree influenced by paleogeoid changes over the globe. The Milankovitch variables sensitively affected the Earth's geoid. This effect is considered to be the main reason for the correlation established between orbital geometry changes and the oxygen isotope fluctuations in the deep sea records. The insulation effects of the Milankovitch variables were therefore rather modulating than controlling the Earth's climate during the Pleistocene. (Author).

226 MORNER, N.-A. 1986. "The Concept of Eustasy: A Redefinition," Journal of Coastal Research, Special Issue No. 1, pp 49-51.

Eustasy can no longer be defined as "worldwide simultaneous changes in sea-level," but must be redefined as "ocean level changes" or any "absolute sea-level changes" regardless of causation and including both the vertical and horizontal changes of the geoid surface as well as changes of the dynamic sea surface topography. In the field, we can only observe the "relative sea-level changes." (Author).

227 MORTON, R. A., and PRICE, W. A. 1987. "Late Quaternary Sea-Level Fluctuations and Sedimentary Phases of the Texas Coastal Plain and Shelf," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 181-198.

The coastal plain and continental shelf of Texas were sites of simultaneous erosion and deposition related to late Quaternary eustatic fluctuations in sea-level. Geologic maps, deep borings, and seismic profiles from the area provide evidence of how the dominant sedimentary processes responded to changes in base level during the most recent (Sangamonian-Holocene) depositional episode.

The early Wisconsinan falling sea-level and subsequent lowstand caused upstream river entrenchment and downstream deltaic progradation beyond the shelf edge. Later, deltaic sedimentation shifted landward in response to a middle Wisconsinan sea-level rise and then seaward in the late Wisconsinan as sea-level fell to its lowest position. Carbonate reefs grew on a broad terrace between the major deltas during the initial postglacial rise in sea-level. The continued sea-level rise (Holocene) and highstand resulted in erosion and retreat of deltaic headlands, progradation of interdeltaic barriers and strandplains, and aggradation of alluvial valleys, bays, and the inner shelf. Modern patterns of shoreline deposition resemble those of the preceding (Sangamonian) highstand.

Local and regional structures controlled the position and thickness of some late Wisconsinan and early Holocene deposits, such as river channels, sand ridges, and carbonate reefs. Lowstand deltas along the basin margin are several times thicker than their updip counterparts because of rapid subsidence and progradation into relatively deep water at the shelf edge. Landward of the shelf edge, however, thicknesses of depositional sequences and individual fluvial, deltaic, and barrier island sand bodies are comparable regardless of whether they were deposited under static or falling sea-level conditions. Apparently, thicknesses of these stable-platform deposits depended nearly equally on subsidence and water depth. (Authors).

228 MOSLOW, T. F., and COLGUHOU, D. J. 1981. "Influence of Sea-Level Change on Barrier Island Evolution," Oceanis, Vol 7, No. 4, pp 439-454.

A detailed stratigraphy examination of Holocene coastal deposits from the southeast Atlantic coast of the United States has documented the over-riding influence of eustatic sea-level fluctuations on barrier shoreline evolution. Sediment supply, pre-Holocene topography and shoreface profiles are other important controls in Late Holocene barrier island development along depositional shorelines adjacent to broad gently sloping, tectonically stable, sandy coastal plains around the world.

The Holocene stratigraphy of two progradational, beach ridge barriers on the South Carolina coast contains a well-preserved record of transgressive (5,800-4,000 B.P.) and regressive (4,000 - 0 B.P.) phases as follows:
1) origin of a primary barrier and initiation of back-barrier sedimentation from 5,800 - 4,500 B.P.; 2) rapid sea-level rise from 4,500 - 4,000 B.P.; migration of the primary barrier to its most landward position and deposition of a shoreface transgressive lag; 3) initiation of barrier progradation from 4,000 - 3,500 B.P., by shoreface accretion as a series of beach ridges; and 4) episodic seaward growth of the barrier complex since 3,500 B.P. This sequence of events is directly correlatable to a separately derived late Holocene eustatic sea-level curve of the South Carolina coast.

Comparison to other beach ridge complexes from around the world suggests an origin for most barrier islands in a primary transgressive phase from 5,800 to 4,000 B.P. Major impetus in barrier genesis is a sharp eustatic sea-level rise around 4,200 - 4,000 B.P. (Authors).

229 MOTO, TETSUJI. 1986. "Coastal Fan Processes Controlled By Sea-Level Changes: A Quaternary Example from the Tenryugawa Fan System, Pacific Coast of Central Japan," Journal of Geology, Vol 95, pp 716-724.

A new hypothesis for dynamic processes in coastal fans is presented, based on the concepts of temporal changes in fan morphology and associated sediment bodies in phased and cyclic mode. These changes, which are marked by overflows from a "fan valley" before its complete burial as well as after the initiation of its entrenchment, are entirely related to relative sea-level changes. The hypotheses is exemplified by the Middle Pleistocene to Holocene Tenryugawa fan system, Pacific coast of central Japan. (Author).

230 MUHS, D.R. 1983. "Quaternary Sea-Level Events on Northern San Clemente Island, California," Quaternary Research, Vol 20, pp 322-341.

Global sea-level changes are expressed in the coastal landforms and deposits of northern San Clemente Island. Stratigraphic, radiometric, amino acid and pedologic dating techniques have allowed the development of a chronology of sea-level changes for about the last 500,000 year. A uranium-series date on coral of about 127,000 year for the 2nd terrace serves as a calibration point for amino acid age estimates of four other mapped terraces. Two of these terraces have age estimates of about 80,000-105,000 year. another has an age estimate of about 127,000 year. and the 5th terrace on the west side of the island is estimated to be about 415,000-575,000 year old. These dates correlates reasonably well with marine terraces dated elsewhere and with stages of the oxygen-isotope record that are thought to represent high stands of the sea. Weakly cemented calcareous dune sands (eolianites) are moderately extensive on northern San Clemente Island and appear to represent low stands of the sea, since calcareous shelf sands were the most likely source. A radiocarbon date of about 22,000 year suggests that the youngest eolianite was deposited during the last glacial maximum. An older eolianite is estimated to be about 140,000-195,000 year old based on stratigraphic relations and degree of soil development. The suggested ages for the eolianites also correlate well with oxygen-isotope estimates of low sea-levels. (Author).

231 MUHS, D. R. 1985. "Amino Acid Age Estimates of Marine Terraces and Sea-Levels on San Nicolas Island, California," Geology, Vol 13, pp 58-61.

Fourteen marine terraces rising to an elevation 274 m have been mapped on San Nicolas Island, California. The lowest terrace is ~105,000 years old, on the basis of amino acid ratios in fossil mollusks slightly lower than those from the ~120,000 year old, uranium-series dated second terrace. The age estimate and present elevation of the lowest terrace, along with an assumption of constant uplift rate, indicate a paleo-sea-level estimate of -10 to -12 m at about 105,000 B.P., supporting the general Barbados model of sea-level history. The fourth and fifth terraces probably represent separate high sea-level stands during the same interglacial complex $\geq$400,000 B.P. The eight and tenth terraces have amino acid ratios near equilibrium and imply ages of

≥600,000 years. Collectively, the data suggest long-term average Quaternary uplift rates of 0.2-0.3 m/1000 years. (Author).

232 MUNK, W., and REVELLE, R. 1952. "Sea-Level and the Rotation of the Earth," American Journal of Science, Vol 250, pp 829-833.

From ancient beach lines, Daly has proposed a eustatic lowering of sea-level by about five ms during the last few thousand years. This would decrease the length of day by 30 milliseconds if the lowering is due to "rapid" growth of ice caps, and by 90 milliseconds if, as suggested by Daly, the lowering is due to isostatic afterflow in the earth's mantle following a rapid melting of ice caps. The corresponding value derived from ancient observations of eclipses, 27±18 milliseconds, indicates rapid growth of ice caps. For the last hundred years, tide gage records and the retreat of glaciers indicate a rise in sea-level by 10 cm. This rise would displace the north pole of rotation by something like 10 ft towards the North Atlantic, the precise value and the direction depending on the source of melted water. Such a displacement is not inconsistent with astronomic evidence. (Authors).

233 MUTO, T. 1987. "Coastal Fan Processes Controlled by Sea-Level Changes: A Quaternary Example From the Tenryugawa Fan System, Pacific Coast of Central Japan," Journal of Geology, Vol 95, pp 716-724.

A new hypothesis for dynamic processes in coastal fans is presented, based on the concepts of temporal changes if fan morphology and associated sediment bodies in phased and cyclic mode. These changes which are marked by overflows from a "fan valley" before its complete burial as well as after the initiation of its entrenchment, are entirely related to relative sea-level changes. The hypothesis is exemplified by the Middle Pleistocene to Holocene Tenryugawa fan system, Pacific coast of central Japan. (Author).

234 MYSAK, L. A. 1967. "On the Very Low Frequency Spectrum of the Sea-Level on a Continental Shelf," Journal of Geophysical Research, Vol 72, No. 12, pp 3043-3047.

The very low frequency and wave number response of the continental shelf adjusted sea-level to a general atmospheric pressure forcing function is obtained. Using this result, an expression for the very low frequency spectrum of the adjusted sea-level is also derived. It is shown that in the region of the atmospheric pressure spectrum maximum, there is good agreement between the theoretical and observed adjusted sea-level spectrums at Sydney, Australia. (Author).

235 MYSAK, L. A., and HAMON, B. V. 1969. "Low-Frequency Sea-Level Behavior and Continental Shelf Waves Off North Carolina," Journal of Geophysical Research, Vol 74, No. 6, pp 1397-1405.

Spectrums and cross spectrums of 12 hourly mean sea-levels and atmospheric pressures at Southport and Morehead City, North Carolina, show that the response of sea-level to pressure is nonbarometric in most of the frequency range studied (0-0.5 cycle/day). Cross spectrums between sea-levels adjusted to constant atmospheric pressure at the two stations show phase shifts consistent with the hypothesis of continental shelf waves traveling in the direction predicted by theory (southward). There is some evidence of a seasonal variation in wave speed, which may be associated with the seasonal variation in the surface speed of the Gulf Stream. Broad peaks in the sea-level spectrums, centered around a period of 15 days, are also thought to be connected with the Gulf Stream current, than with atmospheric pressure. (Authors).

236 NAMIAS, J., and HUANG, J. C. K. 1972. "Sea-Level at Southern California: A Decadal Fluctuation," Science, Vol 177, No. 4046, pp 351-353.

The winter mean height of sea-level at southern California rose 5.6 cm between the periods 1984-1957 and 1958-1969. These periods correspond to two fairly coherent large-scale climatic regimes with different air-sea coupling, which were previously identified. The rise was mainly due to a change in the thermohaline structure of the water as a result of changes in prevailing winds. (Authors).

237 NAMIAS, J. 1976. "Some Statistical and Synoptic Characteristics Associated with El Niño," Journal of Physical Oceanography, Vol 6, pp 130-138.

A 49-year time series of sea surface temperatures along the Peruvian coast is analyzed in order to find antecedent and subsequent indicators of El Niño (abnormally warm water) and its inverse. Precursory signs show up in certain statistics gathered seasons before the event, and these should be useful in forecasting the occurrence or non-occurrence of this economically important phenomenon.

The macroscale processes implied by the above data are explored with the help of Northern Hemisphere pressure patterns and geostrophic wind profiles. There is a strengthening of the North Pacific winter westerlies when El Niño occurs as suggested by Bjerknes, that is, through momentum transports from a variable Hadley cell. However, El Niño appears to be associated with an appreciably weakened Pacific High over the eastern third of the North Pacific during the preceding year. This lends support to the theory that generation of El Niño is a long-term large-scale process in which reduced wind stress permits an accelerated equatorial countercurrent and diminished equatorial upwelling. (Author).

238 NARDIN, T. R., OSBORNE, R. H., BOTTJER, D. J., and SCHEIDEMANN, R.C., JR. 1981. "Holocene Sea-Level Curves for Santa Monica Shelf, California Continental Borderland," Science, Vol 213, pp 331-333.

A curve is constructed showing changes in sea-level at the Santa Monica shelf over the past 18,000 year. The curve is based on radiocarbon dates, sedimentologic data, and high-resolution seismic stratigraphic analysis of late Quaternary terrace deposits. Sea-level was 117 m below its present position about 18,000 year ago. During the first 8000 years of the Flandrian transgression, sea-level rose to at least 24 m, fell to about 46 m, and then rose to 20 m, all below present sea-level. Subsequently sea-level rose more slowly and without discernible interruption to its present position. (Authors).

239 NATIONAL RESEARCH COUNCIL. 1982. "Carbon Dioxide and Climate: A Second Assessment," National Academy Press, Washington, DC, pp 72.

For over a century, concern has been expressed that increases in atmospheric carbon dioxide (CO_2) concentration could affect global climate by changing the heat balance of the atmosphere and Earth. Observations reveal steadily increasing concentrations of CO_2 and experiments with numerical climate models indicate that continued increase would eventually produce significant climatic change. Comprehensive assessment of the issue will require projection of future CO_2 emissions and study of the disposition of this excess carbon in the atmosphere, ocean, and biota; the effect on climate; and the implications for human welfare. This study focuses on one aspect, estimation of the effect on climate of assumed future increases in atmospheric CO_2. Conclusions are drawn principally from present-day numerical models of the climate system. To address the significant role of the oceans, the study also makes use of observations of the distributions of anthropogenic tracers other than CO_2. The rapid scientific developments in these areas suggest that periodic reassessments will be warranted.

The starting point for the study was a similar 1979 review by a Climate Research Board panel chaired by the late Jule G. Charney. The present study has not found any new results that necessitate substantial revision of the conclusions of the Charney report. (Authors).

240 NATIONAL RESEARCH COUNCIL. 1983. Changing Climate, Report of the Carbon Dioxide Assessment Committee, National Academy Press, Washington, DC, pp 496.

The National Research Council, Board on Atmospheric Sciences and Climate and Commission on Physical Sciences Mathematics and Resources, addressed the following issues on carbon dioxide (CO_2):

- A comprehensive assessment of CO_2 release and impacts of CO_2 increase;
- Development of an international research and assessment program and definition of the U.S. role;

- Analysis of domestic resource requirements for international and domestic programs;
- Evaluation of the U.S. government CO_2 program; and
- Assessment of the need for periodic reports and a long-term assessment program.

This book is organized into two major parts that includes an overview or synthesis representing the views of the committee as a whole on the issue and a group of papers each addressing a specific topic or problem area on CO_2. (From Introduction.)

241 NATIONAL RESEARCH COUNCIL. 1987. Responding to Changes in Sea-Level, Engineering Implications, National Academy Press, Washington, DC, pp 148.

This interdisciplinary study of the engineering implications of relative mean sea-level change examines recent sea-level trends; projections of continuing relative change; shoreline response; consequences for engineering works and built facilities; methods for protecting structures from erosion and flooding; and the need for new technologies for mitigation. To provide a useful basis for sensitivity design calculations and policy decisions that must take sea-level rise into account, the committee adopted three plausible variations in eustatic sea-level rise to the year 2100, all displaying a greater rate of rise in the distant future than in the next decade and all with an increased rate of rise relative to the present: 50, 100, and 150 cm.

Over the past century, worldwide sea-level has risen about 12 cm. In many places along the U.S. shoreline, subsidence exceeds the eustatic component by a factor of 2, and in Louisiana by a great factor of 10. In higher latitudes, glacial rebound is much greater than the eustatic component of sea-level rise and, in locations like Hudson Bay, Canada, and resulted in a relative lowering of sea-level in excess of 130 cm/century. These substantial differences must be considered in developing responses to a relative "change". In regards to tide gage, the study concluded that (a) gages located either inside or outside bays are subject to different influences that tend to degrade the quality of the data; (2) with more distant locations inside the bay gages contain a greater quantity of 'noise~ that is not representative of the outside mean sea-level; and (3) in the shore term (over several decades), inside gages will underestimate rise taking place on the open coast. It is recommended that the number of long-term, open-coast tide gages should be increased with a special emphasis on the Southern Hemisphere.

The committee concluded that the most appropriate present engineering strategy is not to adopt one particular sea-level rise scenario, but instead to be aware of the probability of increasing sea-level and to keep all response options open. (Modified Executive Summary).

242 **NEFTEL, A., MOOR, E., OESCHGER, H., and STAUFFER, B.** 1985. "Evidence From Polar Ice Cores For the Increase in Atmospheric CO_2 in the Past Two Centuries," Nature, Vol 315, pp 45-47.

Precise and continuous measurements of atmospheric CO_2 concentration were first begun in 1958 and show a clear increase from 315 parts per million by volume (p.p.m.v.) then to 345 p.p.m.v. now. A detailed knowledge of the CO_2 increase since preindustrial time is a prerequisite for understanding several aspects of the role of CO_2, such as the contribution of biomass burning to the CO_2 increase and the sensitivity of climate to the CO_2 concentration in the atmosphere. Estimates of the preindustrial CO_2 concentration are in the range 250-290 p.p.m.v. (ref. 2), but the precise level then and the time dependence of the increase to the present levels remain obscure. The most reliable assessment of the ancient atmospheric CO_2 concentration is derived from measurements of air occluded in ice cores. An ice core from Siple Station (West Antarctica) that allows determination of the enclosed gas concentration with very good time resolution has recently become available. We report here measurements of this core which now allows us to trace the development of the atmospheric CO_2 from a period overlapping the Mauna Loa record back over the past two centuries. (Authors).

243 **NEWELL, R. E.** 1986. "El Niño: An Approach Towards Equilibrium Temperature in the Tropical Eastern Pacific," Journal of Physical Oceanography, Vol 16, pp 1338-1342.

A different view of El Niño is proposed, namely, that it represents an approach towards the tropical equilibrium temperature of approximately 30° C, set essentially by evaporation, by the waters of the eastern tropical Pacific. (Author).

244 **NEWMAN, W. S., CINQUEMANI, L. J., SPERLING, J. A., MARCUS, L. F., and PARDI, R. R.** 1987. "Holocene Neotectonics and the Ramapo Fault Zone Sea-Level Anomaly: A Study of Varying Marine Transgression Rates in the Lower Hudson Estuary, New York and New Jersey," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 97-113.

Eleven tidal marsh stations along the lower Hudson river estuary yield contrasting marine transgression rates: more than 2.0 m/millennium at New York City compared to about 1.0 m/millennium 100 km to the north at Marlboro near Poughkeepsie. The entire area appears to be tilting downward to the south-southeast. Three tidal marsh stations within the Ramapo Fault Zone (RFZ) yield higher transgression rates as compared to the other stations beyond the limits of the RFZ. This anomaly seems best explained by complex graben-like downfaulting, with a throw of at least 1 m having occurred within the past 2 millennia. There is also evidence, based on radiocarbon dating, of earlier fault movement after about 4.2 ka, suggesting a recurrence interval on the order of 2,000 years. The displacements inferred from these varying transgression rates may result from faults whose traces do not intersect the earth's surface. (Authors).

245 NEWMAN, W. S., and MARCH, S. 1968. "Littoral of the Northeastern United States: Late Quaternary Warping," Science, Vol 160, pp 1110-1112.

Isobases constructed from recently published data are strongly parallel to both the edge of the continental shelf off the northeastern United States and the Fall Zone. Our analyses suggest that the downwarping recorded by these isobases may be explained by Daly's hypothesis of a collapsing peripheral or marginal "bulge." (Authors).

246 NEWMAN, W. S., and RUSNAK, G. A. 1965. "Holocene Submergence of the Eastern Shore of Virginia," Science, Vol 148k, pp 1464-1466.

Radiocarbon ages of basal peats 4500 years old or younger and the thickness of salt-marsh peat in the lagoon east of Wachapreague, Virginia, are nearly the same as those of equivalent samples from New Jersey and Cape Cod. This suggests that these coasts have had similar submergence histories. Data obtained from the coasts of Connecticut and northeastern Massachusetts indicate that the Atlantic coast of the United States has been differentially warped during the late Holocene. (Authors).

247 NUMMEDAL, D. 1983. "Rates and Frequencies of Sea-Level Changes: A Review With an Application to Predict Sea-Levels in Louisiana," Transactions: Gulf Coast Association of Geological Societies, Vol 33, pp 361-366.

The relative elevation of sea and land has been changing throughout time in response to two fundamentally different groups of factors operating globally and locally. (1) Global factors include changes in the volume of the ocean basins due to variable sea floor spreading rates, oceanic sedimentation, continental accretion, and the opening and closing of marginal seas. Furthermore, the mass of oceanic water has changed in response to glaciations, and the specific volume of the water is temperature dependent. (2) Local factors influencing relative sea-level at any measurement station include subsidence of continental margins, fault displacements, compaction due to dewatering of sediments, and a range of atmospheric factors.

This review has identified nine groups of factors which control relative sea-level. These factors operate at distinctly different time scales ranging from 10^8 years (sea floor spreading) to hours (storms). These same groups of factors also have characteristic rates of sea-level change, ranging from 5×10^{-4} cm/year for sea floor spreading to 30 cm/year for seasonal effects due to continental run-off and steric expansion of seawater.

As one application of the data in this review an attempt has been made to predict the trend of relative sea-level along the coast of Louisiana for the coming decades. Currently, the global (eustatic) sea-level appears to be rising at a rate of 1.2 mm per year. The local rate of land surface sinking along the central Louisiana coast appears to be about 9 mm per year.

Based on linear extrapolation of current trends one would predict that local sea-level on the Louisiana coast in the year 2020 would stand about 40 cm higher than the present.

A linear extrapolation of current trends is probably too conservative. Climatic modeling strongly suggests accelerated global warming due to the greenhouse effects of increasing atmospheric CO_2. As a consequence, the global (eustatic) rate of sea-level rise is expected to increase due to steric expansion of the seawater and continued melting of land-based polar ice caps. For the next 40 years eustatic sea-level may rise at a rate of 9 mm/year. On this basis one would predict that local sea-level on the Louisiana coast in the year 2020 would stand about 72 cm higher than the present. Such a rise would result in catastrophic inundation of coastal lowlands.

Global warming also would increase tropical storm frequencies and the extent of coastal storm tide inundation.

The economic impact on south Louisiana due to local sea-level rise is already severe and it is likely to increase in magnitude. It is imperative that plans for coastal development and protection consider these long-term trends. (Author).

248 NUMMEDAL, D., CUOMO, R. F., PENLAND, S. 1984. "Shoreline Evolution Along the Northern Coast of the Gulf of Mexico," Shore and Beach, pp 11-17.

The first paper in this series demonstrated that local relative sea-level along the Louisiana coast currently is rising at an average rate in excess of one centimeter per year. Only about 10 percent of this rise appears to be eustatic, the remainder is due to sinking of the Louisiana coastal plain in response to loading-induced dewatering of modern muds and subsidence of older strata.

Louisiana also has the most rapidly changing shoreline in the United States. According to the coastal research group at the University of Virginia, Louisiana is the only state where the average annual retreat rate exceeds 3 m/year. As documented by Penland et al. shoreline erosion rates along many segments of the Louisiana coast exceed 15 m/year. Gerdes and Penland et al. documented with studies of historical maps that the Louisiana mainland coast at Caminada and the barrier island coast off Terrebonne Parish (Isle Dernieres) both have retreated more than 2 km since the 1850's.

The correlation between rapid sea-level rise and dramatic coastal retreat in Louisiana is undeniable. It is the purpose of this paper to examine the role that sea-level rise has played in this shoreline change. (Introduction).

249 NUMMEDAL, D., and SWIFT, D. J. P. 1987. "Transgressive Stratigraphy at Sequence-Bounding Unconformities: Some Principles Derived From Holocene and Cretaceous Examples," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution: Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 241-260.

Sequence stratigraphic concepts are powerful tools in the analysis of the evolutionary history of sedimentary basins. The criteria used in the identification of depositional sequences differ for outcrop and subsurface data sets because of scale differences in stratal continuity and spatial resolution. This paper documents sedimentary and stratigraphic characteristics of sequence boundaries and the overlying transgressive succession of depositional systems. By emphasizing the sedimentology and the different patterns of systems stacking above the sequence boundaries, this paper aids in identifying these key stratigraphic boundaries in outcrop.

The key stratigraphic surfaces encountered in shallow marine sedimentary sequences are: (1) subaerial unconformities, cut by episodes of sea-level fall, and representing a significant hiatal break; and (2) diastems, surfaces representing relatively short interruptions in sedimentation. Most diastems in shallow marine and coastal settings are associated with transgressions and may be loosely grouped as "transgressive surfaces." Diastems include the ravinement diastem, which is formed by transgressive shoreface retreat, channel-base diastems, and various marine erosion diastems.

Subaerial unconformities of regional or interregional extent and their correlative marine unconformities and conformities serve as boundaries of depositional sequences. The depositional architecture between the sequence boundary and the overlying transgressive surface, e.g., the ravinement diastem, is controlled by the relief of the coastal plain and the rate of transgression.

Transgression of a coastal plain previously dissected by an episode of significant sea-level fall will produce shore-normal estuaries and shore-parallel lagoons. The resultant stratigraphic succession will be characterized by an inner-shelf sand sheet above back-barrier deposits and "ribs" of fluvial and estuarine sediments filling former subaerial valleys. this architecture characterizes the Holocene stratigraphy of the United States Atlantic and Gulf shelves, and the basal Cretaceous strata (Oak Canyon Mbr of the Dakota Sandstone) of the San Juan basin in New Mexico.

In rapidly subsiding basins, such as the Holocene Mississippi Delta region of the Gulf Coast basin and the western foredeep area of the Cretaceous Interior Seaway, relative sea-level fall may be insignificant or nonexistent. Consequently, the sequence boundary may be a rather subtle unconformity, or even a conformity. Nevertheless, the transgressions will cause erosional shoreface retreat, the cutting of ravinement diastems ad formation of offshore erosion surfaces. These surfaces generally are of limited spatial extent and are discontinuous in the stratigraphic record, yet, they form distinct lithostratigraphic breaks and may easily be mistaken for sequence boundaries. Time lines cross these transgressive surfaces, but they do not cross sequence boundaries.

The Coniacian strata of the San Juan basin provide an example of a sequence boundary and associated transgressive depositional systems formed in response to a relatively small sea-level fall and subsequent rise in a rapidly subsiding basin. A mid-Coniacian sea-level fall, detectable across the entire

Western Interior Seaway, caused the western coastal plain rivers to return to grade by depositing a coarse fluvial sandstone (Torrivio Mbr of the Gallup Sandstone), enhanced the bypassing of fines, and intensified storm-induced coarse-grained sediment transport onto the distal shelf (Cooper Arroyo and basal Tocito Sandstones). The subsequent transgression resulted in shoreface retreat by destruction of distributary mouth bars of the Torrivio Mbr, formation of offshore linear shelf sand ridges above the ravinement diastem (Tocito Sandstone ridges), the deposition of a series of transgressive sand bodies in back-barrier settings (e.g., flood-tidal deltas of the Borrego Pass Sandstone), and rapid accretion of low-energy fluvial facies (Dilco Coal Mbr of the Crevasse Canyon Fm). Individual ravinement surfaces underlie many Tocito Sandstone ridges and separate them from regressive facies, but these surfaces may be of limited areal extent and are probably not connected to a single regional unconformity. The ravinement surfaces and the transgressive Tocito sandstones climb progressively higher in the section relative to the mid-Coniacian sequence boundary as one moves updip (paleo-landward). (Authors).

250 OERLEMANS, J. 1981. "Effects of Irregular Fluctuations in Antarctica Precipitation on Global Sea-Level," Nature, Vol 290, pp 770-772.

One of the reasons for the continuing interest in the global sea-level is that secular variations may be caused by climatic changes. Such a change could, for example, be an atmospheric warming due to CO accumulation. Changes in the amount of ice in the major ice sheets will be reflected in secular variations of sea-level; it has, for example, been suggested that ice-shelf thinning may change the drainage of parts of the Antarctic Ice Sheet. Attempts to monitor climatic change by measuring global sea-level will, however, be complicated by random variations in the ice accumulation rate. Precipitation rates are highly variable, and this also applies to Antarctica, which stores most of the continental ice mass. By means of a simple model for ice flow in the Antarctica, together with proxy data on precipitation variability derived from ice cores, I show that long-term sea-level variations with a standard deviation of roughly 5 cm are to be expected on this account. This "climatic noise" is comparable in magnitude with many of the secular effects now being sought. (Author).

251 OFFICER, C. B., and DRAKE, C. L. 1985. "Terminal Cretaceous Environmental Events," Science, Vol 227, No. 4691, pp 1161-1167.

The geologic record of terminal Cretaceous environmental events indicates that iridium and other associated elements were not deposited instantaneously but during a time interval spanning some 10,000 to 100,000 years. The available geologic evidence favors a mantle rather than meteoritic origin for these elements. These results are in accord with the scenario of a series of intense eruptive volcanic events occurring during a relatively short geologic time interval and not with the scenario of a single large asteroid impact event. (Authors).

252 **OLDALE, R. N.** 1985. "Rapid Postglacial Shoreline Changes in the Western Gulf of Maine and the Paleo-Indian Environment," American Antiquity, Vol 50, No. 1, pp 145-150.

Rapid shoreline regression and transgression along the western Gulf of Maine between 13,000 and 9000 years B.P. are inferred to have produced a nearshore marine environment low in biologic productivity. Paleo-Indians living near the coast of the Gulf were probably forced to rely on nonmarine resources landward of the late-glacial marine limit. Thus, Paleo-Indian sites of the time period in question may be restricted in the region between the marine limit and the postglacial low sea-level stand, or may be altogether absent. (Author).

253 **OLDALE, R. N.** 1985. "Late Quaternary Sea-Level History of New England: A Review of the Published Sea-Level Data," Northeastern Geology, Vol 7, No. 3/4, pp 192-200.

Sea-level curves are used by archaeologists and geologists to locate paleoshorelines and to reconstruct ancient coastal environments. A review of relative sea-level curves available for the southern New England coast indicates that the relative high sea-level events proposed for the intervals of 35,000 B.P. and about 12,000 B.P. probably did not occur. Any curve that covers the interval between 12,000 B.P. and 5,000 B.P. is based largely on imprecise data and is only approximately correct. Curves controlled by dates on basal peat from marshes suggest a sea-level rise along the south coast of about 3 m/1,000 years from about 8,000 B.P. up to about 2,500 B.P. and about 1 m/1,000 years from then to the present. Sea-level data from the western Gulf of Maine and coastal New England from Boston northward indicate a complex history of late Wisconsinan transgression, early Holocene regression, and middle to late Holocene transgression. The timing and magnitude of the highstand are well established but for the lowstand, they are not. Curves based on dated basal peats for the northern coast indicate a middle to late Holocene rise in relative sea-level that is comparable to the south shore of New England. (Author).

254 **OLDALE, R. N. and O'HARA, C. J.** 1980. "New Radiocarbon Dates From the Inner Continental Shelf Off Southeastern Massachusetts and a Local Sea-Level Rise Curve," Geology, Vol 8, pp 102-106.

New radiocarbon dates on shells and freshwater peat are used to draw a curve representing local sea-level rise for the past 12,000 year. The samples were collected near the late Wisconsin glacial maximum where the Continental Shelf suffered the least and most rapid isostatic subsidence and rebound to the advance and retreat of the ice. Because the samples are from quiet-water embayments, they most likely have not been reworked or transported. For these reasons, the curve based on these data is believed to accurately represent sea-level rise in southeastern Massachusetts. Previously published radiocarbon dates from elsewhere on the inner shelf tend to reinforce the curve

proposed here and suggest that the curve may be applicable for much of the inner Continental Shelf off the northeastern United States.

The proposed sea-level-rise curve indicates that relative sea-level was about 70 m below its present level 12,000 year ago. From that time to about 10,000 year ago, sea-level rose at a rate of 1.7 m/100 year. Between 10,000 and 6,000 year ago, the rate of sea-level rise dropped gradually to about 0.3 m/ 100 year and remained at that rate until about 2,000 year ago. From then until now, the rate of sea-level rise has been about 0.01 m/100 year. (Authors).

255 OLSSON, R. K. 1988. "Foraminiferal Modeling of Sea-Level Change in the Late Cretaceous of New Jersey," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 289-298.

Paleoslope models of foraminifera in the Upper Cretaceous of the New Jersey coastal plain are utilized to estimate paleobathymetric change during cycles of rising and falling sea-level. The paleoslope method estimates change in sea-level from the distribution of foraminiferal assemblages and species on a baseline parallel to the regional dip. The paleoslope is the restoration of the original depositional slope. Application of the paleoslope model to the Campanian of New Jersey indicates a maximum rise of sea-level of 90 m and 80 m, respectively, during two cycles of sea-level change. By extension, a paleodepth curve is derived for the other cycles in the Late Cretaceous. Eight cycles are recognized in the Late Cretaceous section of New Jersey. (Author).

256 ORSON, R., PANAGEOTOU, W., and LEATHERMAN, S. 1985. "Response of Tidal Salt Marshes of the U.S. Atlantic and Gulf Coasts to Rising Sea-Levels," Journal of Coastal Research, Vol 1, No. 1, pp 29-37.

A salt marsh responds in many diverse ways to a rising sea-level. A major factor is its ability to maintain surface elevations with respect to the mean high water level. Other influences include local submergence rates, sedimentation rates, density and composition of the indigenous flora, and type and intensity of cultural modifications. If sea-level rise accelerates, it would be reasonable to assume that further stresses will be placed on these systems, most likely resulting in increased losses. If the relative rate of sea-level rise reaches catastrophic proportions (exceeding 10 mm $year^{-1}$), substantial reductions in wetland area and a corresponding increase in open water habitats is projected. Due to the complex interrelationship of natural processes and cultural alterations that have previously influenced marshes, it is difficult at the present time to separate and identify responses. Thus, each marsh must be assessed individually until we have a more thorough understanding of these systems in general. (Authors).

257 OTA, Y., BERRYMAN, K. R., HULL, A. G., MIYAUCHI, T. and ISO, N. 1988. "Age and Height Distribution of Holocene Transgressive Deposits in Eastern North Island, New Zealand," Palaeogeography, Palaeoclimatology, Palaeoecology, Vol 68, No. 2-4, pp 135-151.

Holocene transgressive deposits are frequently exposed near the present-day coastline of the study area along eastern North Island, New Zealand. They occur in sites of former estuaries that were filled during the postglacial rise in sea-level. We present 100 radiocarbon dates of Holocene transgressive deposits from the study area, ranging in age from circa 10,000 to 5,500 year BP. Relative sea-level curves up to circa 6,000 year BP were reconstructed for six locations. The curves have similar slopes prior to about 7000 year BP, indicating that sea-level rise was much more rapid than any tectonic uplift at that time. (Modified Abstract).

258 OWEN, R. M., and REA, D. K. 1985. "Sea-Floor Hydrothermal Activity Links Climate to Tectonics: The Eocene Carbon Dioxide Greenhouse," Science, Vol 227, pp 166-169.

Two important findings of recent ocean-floor drilling in the southeast Pacific (Deep Sea Drilling Project Leg 92) are that sea-floor hydrothermal activity may fluctuate through time by as much as an order of magnitude and that episodes of greatest hydrothermal flux correspond to times when ridge-transform plate boundaries are undergoing major changes in their configuration rather than to known times of increased spreading rate or volcanism. Evidence is presented here in support of the hypothesis that heightened hydrothermal activity induced by the Eocene tectonic activity caused a global greenhouse effect, which may represent the long-sought-after historical analog to the carbon dioxide-induced global warming expected to occur by the middle of the next century. (Authors).

259 PALUMBO, A., and MAZZARELLA, A. 1985. "Internal and External Sources of Mean Sea-Level Variations," Journal of Geophysical Research, Vol 90, No. C4, pp 7075-7086.

The joint variation of monthly mean sea-level, rainfall, and evaporation recorded in Naples and in other western Mediterranean stations is analyzed. The mass balance among sea-level, rainfall, and evaporation and the application of the Wiener filter methods show that the major portion of sea-level variance concentrated at annual and semiannual components is dominated by evaporation; the effect of rainfall is less than the effect of evaporation; the Atlantic water flux acts as a balancing source of sea-level fluctuations among those of rainfall and evaporation. (Authors).

260 PARKINSON, R. W. 1988. "Decelerating Holocene Sea-Level Rise and Its Influence on Southwest Florida Coastal Evolution: A Transgressive/Regressive Stratigraphy," Journal of Sedimentary Petrology, Vol 59, No. 6, pp 960-972.

The Ten Thousand Islands (TTI) are a myeariad of low-relief mangrove islands that lie along the low energy, subtropical southwest Florida coast. The region has been subjected to a relative rise in Holocene sea-level, which has continuously decelerated to its present rate.

Data derived from surface and subsurface sampling indicate that the Holocene sediment package of the TTI area consists of two sediment sequences. The lower sequences consists primarily of 1) biogenic shallowing upwards sequences or 2) thickened mangrove peat layers, reflecting island emergence and shoreline stabilization, respectively. Island emergence compartmentalized the area, further reducing wave and current energy and promoting the infilling of the protected bays through deposition of organic-rich shelly mudstone and wackestone. Based on coastal stratigraphy and ^{14}C dates, the formation of this transgressive/regressive sediment sequence is directly related to changing rates of Holocene sea-level rise, reported to have occurred between 3,500 and 3,200 YBP.

Continued regressive sedimentation could eventually generate a 5-10 m thick transgressive/regressive sediment couplet, with an aerial extent of over 300 km^2, in roughly 10,000 years. This externally forced sediment couplet compares remarkably well to individual small scale transgressive/regressive cycles which repeat tens to hundreds of times throughout the geologic record (see James 1984). The results of this study thus support the allocyclic mechanism as a viable working hypothesis for the generation of these small scale rock cycles. (Author).

261 PATTULLO, J., MUNK, W., REVELLE, R., and STRONG, E. 1955. "The Seasonal Oscillation in Sea-Level," Journal of Marine Research, Vol 14, pp 88-155.

On the basis of all available tide gage records, bathythermograms, and Nansen bottle casts, we have compiled, on a global scale, monthly departures of recorded and steric sea-levels from their annual means. The steric fluctuation is defined in terms of the seasonal fluctuation in specific volume. The results are given in the appendices and in three charts, together with error estimates. In general, the departures are comfortably above the uncertainties introduced by year to year variations and by the effects of local topography.

Recorded and steric departures agree remarkably well in low and temperate latitudes (conditions are isostatic). In these regions the steric levels are associated largely with temperature fluctuations in the upper 100 m. In high latitudes conditions are indeterminate.

Pronounced semiannual fluctuations are found along the west coast of South Africa, in Indonesia, in corresponding regions of the Labrador and Oyashio currents, and in the Gulf of Mexico and adjoining Gulf Stream stations (but not in the Kuroshio!). Elsewhere the oscillations are largely annual in character, with low sea-level in each hemisphere during its spring and with high level during the fall. Recorded amplitudes vary from a few centimeters in the tropics to a few decimeters at higher latitudes; they exceed one m in the Bay of Bengal. Atmospheric pressure effects and long period astronomic tides account for only a small part of the recorded fluctuations. (Authors).

262 PENG, T.-H., and BROECKER, W. S. 1984. "Ocean Life Cycles and the Atmospheric CO_2 Content," Journal of Geophysical Research, Vol 89, No. C5, pp 8170-8180.

The possibility that changes in the ocean's Redfield ratios, in the ocean's plant productivity, or in the extent to which organic material is recycled within the ocean have significantly altered the atmosphere's CO_2 content over the past century is examined. Models show that the magnitudes of the alteration in these processes necessary to produce significant CO_2 changes are unreasonably large. For those who do not wish to accept this theoretical approach, we offer a means to directly monitor the impacts of life cycle changes. It involves determining temporal trends in the dissolved O_2, NO_3, and PO_4 contents of thermocline waters. While surveys carried out in 1972 (GEOSECS) and in 1981 (Transient Tracers in the Ocean) reveal no significant trend for the thermocline of the North Atlantic over this 9-year period, a longer period of observation will be necessary before firm limits can be placed through this observational approach. (Authors).

263 PENLAND, S., RAMSEY, K. E., MOSLOW, T. F., and WESTPHAL, K. A. 1986 "Relative Sea-Level Rise and Subsidence in Louisiana and the Gulf of Mexico," Louisiana Geological Survey, Coastal Geology Technical Report, Baton Rouge, LA.

Two tide gage networks in Louisiana and the northern Gulf of Mexico were analyzed to determine local and region trends in relative sea-level rise and to determine subsidence using eustatic correction factors. Relative sea-level rise rates in Louisiana range between 0.33 cm/year and 1.28 cm/year. Within the Mississippi River delta plain, the Houma tide gage documented a maximum relative sea-level rise rate of 1.24 cm/year for the entire record with rates accelerating from 0.07 cm/year to 1.94 cm/year between 1946 and 1983. On the coast, the Eugene Island tide gage documented a maximum relative sea-level rise rate of 1.19 cm/year with rates accelerating from 0.95 cm/year to 2.17 cm/year between 1939 and 1979. A comparison of other tide gage stations exceeding 30 years or more in record with the Houma tide gage station indicates relative sea-level is rising faster in Terrebonne Parish than anywhere else in Louisiana. Representative water level histories from the Chenier Plain, Teche Basin, Terrebonne Delta Plain, Barataria Basin, St. Bernard Delta Plain, and Ponchatrain Basin indicate the regional rates of relative sea-level rise decrease east and west away from the Terrebonne Delta plain. Rates of relative sea-level rise in the Teche Basin reach a maximum of 1.71 cm/year at Calumet, however these rates are affected by the Atchafalaya River.

In comparison with other National Ocean Survey tide stations throughout the U.S. Gulf Coast, Terrebonne Parish is experiencing the highest relative sea-level rise at 1.19 cm/year. In the surrounding coastal states, relative sea-level rise rates decreases from 0.62 cm/year at Galveston, Texas to 0.15 cm/year in Biloxi, Mississippi. Mean relative sea-level rise in Louisiana is more than 5 times the Gulf of Mexico relative sea-level rise rate average. A comparison of the Eugene Island relative sea-level rise rate of 1.19 cm/year with the global relative sea-level rise rate of 0.12 cm/year

indicates relative sea-level is rising 10 times faster in Terrebonne Parish than the eustatic-sea-level rise average.

The rapid rate of relative sea-level rise observed in Louisiana is attributed to the contribution of compactional subsidence of the Mississippi River delta plain. Louisiana directly overlies the entrenched Pleistocene valley of the Mississippi River, which is infilled by a 300 m thick sequence of Holocene deltaic sediments. A rapid acceleration in relative sea-level rise can be documented by both USACOE and NOS data sets throughout Louisiana and the Gulf of Mexico. (Authors).

264 PENLAND, S., RAMSEY, K. E., McBRIDE, R. A., MESTAYER, J. T., and WESTPHAL, K. A. 1986. "Relative Sea-Level Rise, Delta Plain Development," Louisiana Geological Survey, Coastal Geology Bulletin Number 1.

The Louisiana Geological Survey at Louisiana State University conducted a detailed investigation of sea-level rise, delta-plain development, and wetland sedimentation in the Terrebonne Parish region using tide gage records, geomorphic information, stratigraphic information, radiometric dating techniques, and geodetic leveling data for the Terrebonne Parish Consolidated Government. Recent research results indicate that global relative sea-level is rising at a rate of 0.12 cm/year; in the Gulf of Mexico the relative rate of sea-level rise is slightly higher at 0.23 cm/year. Relative sea-level rise is defined as the combined effect of global or eustatic sea-level rise and local subsidence. The Houma tide gage station on the Intracoastal Waterway measured a relative sea-level rise rate of 1.28 cm/year.

Using a eustatic correction factor of 0.23 cm/year for tide gage station records from the Gulf of Mexico, the authors estimate rates of subsidence in Houma at 1.03 cm/year. The results of the geodetic leveling analysis indicate that the rate of subsidence ranges between 0.24 cm/year and 1.60 cm/year with a mean rate of 0.92 cm/year. These rates correlate closely with the eustatic-corrected tide gage results. From stratigraphic analysis, it was determined a mean subsidence rate of 0.66 cm/year for the last 500 years and 0.19 cm/year for the period 500-4000 year B.P. Subsidence rates tend to decrease east and west away from Houma and increase toward the coast as a function of the underlying Holocene delta-plain thickness. A comparison of relative sea-level rise and subsidence rates indicates that subsidence is the major component driving relative sea-level rise under current conditions.

The average wetland sedimentation rate is 0.86 cm/year in Terrebonne Parish. Sedimentation rates increase east to west from 0.58 cm/year at Cocodrie to greater than 2.0 cm/year in the Atchafalaya River area. It should be noted that adjacent to the Atchafalaya River and east of Avoca Island sedimentation rates decrease to 0.81 cm/year owing to the presence of the levee system. In general, under the current sea-level rise conditions, marsh accretion rates are not sufficient to maintain the coastal wetlands within the Terrebonne Parish region except in isolated areas surrounding the Atchafalaya River. (Modified Abstract).

265 PENLAND, S., SUTER, J. R., and MCBRIDE, R. A. 1987. "Delta Plain Development and Sea-Level History in the Terrebonne Coastal Region, Louisiana," Proceedings of Coastal Sediments '87, Vol II, pp 1689-1705.

The Terrebonne coastal region is located on the south central portion of the Mississippi River delta plain. The depositional history of this area was investigated using vibracores, seismic profiles, radiometric dating techniques and tide gage record analysis. A new chronostratigraphic model depicting Lafourche and Teche delta complex development is presented. Eustatic-enhanced and isostatic sea-level changes were delineated based on the correlation of regressive and transgressive delta-plain sequences with regional and localized ravinement surfaces. Tide gage analysis indicates the Terrebonne coastal region is faced with potentially catastrophic land loss conditions over the next century if current relative sea-level rise acceleration rates of 1.03-1.28 cm/year continue. (Authors).

266 PILKEY, O. H., and DAVIS, T. W. 1987. "An Analysis of Coastal Recession Models: North Carolina Coast," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 59-70.

Using the North Carolina barrier island shoreline as the test area, a variety of simple geometric recession models has been applied to predict shoreline erosion rates for various sea-level rise scenarios. All sea-level rise scenarios assume no acceleration in rate of rise. South of Cape Lookout, the slope of the migration surface predicts a much greater recession than Bruun-related models. This suggests the possibility that the islands are in an "out-of-equilibrium position" with respect to present sea-level. If this is the case, the possibility exists that very rapid migration of the northern islands will soon occur.

The assumptions used in the present mathematical models depicting shoreline retreat are generally weak. Better models are needed, especially for shorelines where recession is part of the barrier island migration process. The large number of types of islands in a wide variety of geologic and oceanographic settings makes a universally applicable model difficult, if not impossible, to formulate. (Authors).

267 PILKEY, O.H., Jr., and HOWARD, J. D. 1981. "Saving the American Beach: A Position Paper by Concerned Coastal Geologists," Skidaway Institute of Oceanography Conference on America's Eroding Shoreline, Savannah, Georgia, pp 12.

New approaches to the management of the American shoreline are urgently needed to preserve our recreational beaches for future generations. Approximately half of the 10,000 miles of the "lower 48" American shoreline facing the open ocean is under development pressure. Well over 2,000 miles are considered by the U.S. Army Corps of Engineers to be in a state of critical erosion. Erosion is occurring along almost all of the U.S. coast and when

shoreline retreat collides with shoreline development, a state of "critical erosion" is achieved. Shoreline retreat is due to many causes but a major one is rising sea-level and indications are that the rise will continue for the foreseeable future.

The usual response to critical erosion on America's shore is stabilization; halting of shoreline retreat by engineering means. Such stabilization of America's shore has been successful in increasing the length of life of buildings built adjacent to the beach. However, stabilization in the long run (50 years $\pm$) and sometimes in a much shorter time frame has resulted in severe degradation of the recreational beach area. Dollar costs of halting shoreline retreat by stabilization is very high. Replacement of the beach by pumping in new sand costs about 1 million dollars or more per shoreline mile each time it is done and it must be carried out repeatedly commonly in 3 to 10 year intervals. Another approach, the building of seawalls, costs between $100 to $600 per linear open ocean shoreline ft. Combining these cost figures with the 2,000 mile figure of critically eroding shoreline gives some idea of the magnitude of the potential economic crisis on the American shoreline if we continue to stabilize.

Stabilization costs can be justified for major coastal cities or harbor entrances (Chicago, Galveston, Miami Beach, Coney Island, the Columbia River entrance, for example), but stabilization of most American shores is not justifiable in the broader scope of national interest. Numerous projects involving public and private money along virtually all developed coastal and lake shores presently threaten most of America's recreational shoreline.

The consequences of responding to rising sea-level by shoreline stabilization are so serious that we urge immediate measures to explore totally new approaches to shoreline management. Such approaches may even involve drastic and unpopular measures such as assuming that building adjacent to the beach are temporary or expendable. Equally important, the new approach to shoreline management must incorporate the very significant advances in geologic understanding of shoreline processes that have occurred during the last decades. In the past the American public has been largely unappraised and unaware of the long range environmental and dollar costs of shoreline stabilization. There is a critical and immediate need for the public to know the direction in which American shoreline management is leading. (Modified Summary).

268 PINTER, N. and GARDNER, T. W. 1989. "Construction of a Polynomial Model of Glacio-Eustatic Fluctuation: Estimating Paleo-Sea-Levels Continuously Through Time," <u>Geology</u>, Vol 17, No. 4, pp 295-298.

Sea-level curves for the late Quaternary are typically reconstructed with data from reef tracts and terraces preserved along actively uplifting coastline, recording highstands, and in some cases lowstands, of the world's oceans through time. As a result, sea-level curves reconstructed from these data are fixed at the maxima (highstands) and minima (lowstands), but either make no predictions about the intervening time or use arbitrary or free-hand methods of interpolation. These curves fail to meet the need of many applications of sea-level data for continuous, quantitative information.

A new method for calculating sea-levels during intervening times produces a polynomial expression of sea-level through time. LaGrange polynomial interpolation is used to fit a series of fourth-order equations to

existing data of late Quaternary sea-level elevations with time. The method is germane to any and all models of sea-level based on discrete data points. Here the model advanced by Bloom et al. is reexamined, and a new polynomial model which estimates eustatic sea-levels continuously in the range 0-140 ka is developed from the Huon data. The method includes an error-analysis procedure that accounts for the effects of error in radiometric dates and theodolite measurements in the original data set, and extrapolates this error through the continuous model. Polynomial form and error estimation are indispensable to rigorous quantitative applications of sea-level data and supplant less-rigorous methods used to approximate sea-level and rates of sea-level rise. (Authors).

269 **PIRAZZOLI, P. A.** 1986. "Secular Trends of Relative Sea-Level (RSL) Changes Indicated by Tide-Gage Records," Journal of Coastal Research, Special Issue, No. 1, pp 1-26.

This paper gives the preliminary results of a new investigation based on the records of 1,178 stations provided by the Permanent Service for Mean Sea-level or found in the literature. The longest series available show that oscillations in Relative Sea-level (RSL) can be averaged satisfactorily by linear trends of secular variation when long enough periods of observation are considered. The calculation has been limited to those stations providing at least 50 year-long records and to some stations where the records are only 30 to 50 years long, if the 5-year fluctuations of the RSL are weak during the period of observation. This makes a total of 229 stations for which updated trends of secular variation are now available.

Most of the stations indicate positive upwards trends of secular variation, but at rates changing from one place to another. The conclusion is reached that tectonic and oceanic factors are more important than average global eustatic factors and that the average of all the trends indicated by tide-gage stations may be biased towards a RSL rise by systematic downwarping of coastlines. On a local scale, secular trends of RSL provide very useful information on relative vertical movements of regional land masses and, in some cases, on large scale meanderings of major oceanic currents. (Authors)

270 **PIRAZZOLI, P. A., and MONTAGGIONI, L. F.** 1988. "Holocene Sea-Level Changes in French Polynesia," Palaeoclimatology, Palaeogeography, Palaeoecology, Vol 68, No. 2-4, pp 153-175.

New data on Holocene sea-levels have been obtained in 28 atolls and 10 high islands in the Society, Tuamotu, Gambier and Austral Islands, in an area of the South Pacific as wide as western Europe. Sea-level indicators are often very accurate an include exposed corals, abandoned algal ridges an reef frameworks in growth position, emerged tidal notches, and skeletal reef conglomerates in which the position of the former low water level at the time of cementation has been determined by petrological analysis. Over 110 new samples have been dated by radiocarbon. The overall pattern is that of a MSL standstill at +0.8/1.0 m between 5000 and 1250 year BP. A set of radiocarbon dated samples covering the period 4500 -1250 year BP almost continuously is

evidence that lasting MSL drops could not ever have occurred below +0.7 m throughout this time. The highest sea-level peak (about +1.0 m) seems to have been reached between 2000 and 1500 year BP. Since 1500 year BP MSL has been dropping gradually from about 1.0 m to the present position, which has been reached only recently. Some islands show however a slightly different pattern. Possible geodynamic, isostatic, oceanic and climatic causes of the sea-level variations observed are discussed. (Authors).

271 PIRAZZOLI, P. A., MONTAGGIONI, L. F., THOMMERET, J. & Y., and LABOREL, J. 1985. "Late Holocene Crustal Movements in Rhodes Island, Greece, as Inferred from Shoreline Displacements," Journal of Petroleum Technology, Vol 17, No. 5, pp 589-593.

A systematic survey of the recent shorelines along the east coast of the island of Rhodes enabled us to identify eight small blocks of lithosphere (5 to 20 km long), each having a different tectonic behavior. Each block bears the marks of from 1 to 8 emerged shorelines; traces of recent submergence are also found. Some of these shorelines have been dated by either ^{14}C or by archaeological criteria. For at least three, petrologic analysis indicates the existence of the sequence: emergence-submergence-new emergence.

Blocks also show the effects of uplifting, sinking and tilting often independent of neighboring blocks. Over the last 4500 years, the east coast of Rhodes shows a tendency for upheaval which begins in the south and progressively grows northward where it eventually attains mean rates 1.0 mm per year. The direction of recent movements agrees well with long-term neotectonic trends. However, for the last 4500 years, emergence velocity has clearly surpassed those which prevailed since the Plio-Pleistocene and the Tyearrhenian. (Authors).

272 PIRAZZOLI, P. A., MONTAGGIONI, L. F., VERGNAUD-GRAZZINI, C. and SALIEGE, J. F. 1987. "Late Holocene Sea-Levels and Coral Reef Development in Vahitahi Atoll, Eastern Tuamotu Islands, Pacific Ocean," Marine Geology, Vol 76, No. 1987, pp 105-116.

Preliminary quantitative data are provided on the latest stage of development and morphological evolution of the closed atoll Vahitahi, in the eastern Tuamotus.

From before 4300 to at least 2400 years B.P. sea-level was at least 0.7 m higher than at present. During this time the development of a flat reef pavement, now slightly emerged, gradually separated the lagoon from the ocean. At about 1200 years. B.P. the water level of the lagoon, already closed, was still slightly above the present level.

The response of the reef was a rapid upward accretion until about 3000 years. B.P., then an oceanward development at rates averaging from 0.04 to 0.13 m year $^{-1}$. (Authors).

273 **PLINT, A. G.** 1988. "Sharp-Based Shoreface Sequences and 'Offshore Bars' in the Cardium Formation of Alberta: Their Relationship to Relative Changes in Sea-Level," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 357-370.

Under conditions of stable sea-level, the progradation of a wave-dominated clastic shoreface will give rise to a coarsening-upward sequence, reflecting an increase in the frequency and volume of sand transport with time. Core and well-log data from the Cardium Formation (Turonian) of Alberta reveal two types of shelf-to-shoreface sequences: (1) gradational-based sequences that steadily coarsen upward from thin-bedded, wave-rippled sandstone and mudstone through hummocky cross-stratified (HCS) sandstone and mudstone into mud-free, swaley cross-stratified (SCS) sandstone capped by a root bed, and (2) sharp-based sequences that consist of SCS sandstone, which , near the base, may contain large mudstone intraclasts, sharply overlying thin-bedded sandstone and mudstone: The HCS interval is thin or absent. Log cross sections show that the changes from a gradational to a sharp-based sequence is accompanied by a lowering of both the top and bottom of the SCS sandstone, relative to upper and lower markers. Simultaneously, the SCS sandstone may thin from 15 to 18 m to as little as 6 m. The sharp base, the presence of intraclasts, and the relative lowering o the SCS unit suggest deposition during a rapid fall of relative sea-level during which the shoreface prograded over an erosion surface cut into the inner shelf by fair-weather wave scour.

Tens of kilometers seaward of Cardium shoreface sandstones lies a series of shore-parallel, lenticular bodies ("offshore bars") of conglomeratic muddy sandstone. The lenticular bodies rest on regional erosion surfaces that can be traced landward into slightly older shoreface deposits. The conglomerates are here interpreted as lowstand shoreface deposits, which lie on erosion surfaces cut into the shelf by wave scour during a relative sea-level fall. The stratigraphic and lithologic relationships demonstrable from the Cardium Formation suggest that a number of sharp-based "offshore bar sandstones" in other parts of the Western Interior Seaway may also be more satisfactorily explained as lowstand shoreface deposits. (Author).

274 **POAG, C. W.** 1973. "Late Quaternary Sea-Levels in the Gulf of Mexico," Transactions, Gulf Coast Association of Geological Society, Vol 23, pp 394-400.

The definitive data for late Quaternary sea-levels in the Gulf of Mexico primarily are based on the presence of submerged shoreline depositional features. The accompanying few radiocarbon dates are inadequate to clearly define the chronology of stillstands and regressions during the "post glacial" rise. During the last three years new evidence has been gathered from wavecut terraces and erosional unconformities present on submerged banks near the edge of the northern Gulf continental shelf. At least 26 distinct levels can be recognized between 2 and 223 m, and there are numerous additional minor ones. Most have been interpreted as having resulted from eustatic changes, but it is now clear that tectonic and isostatic movements are also involved. Renewed study of the geomorphology, sedimentology, and stratigraphy of the bank

deposits coupled with extensive radiocarbon dating can clarify the late Quaternary marine sequence in the Gulf of Mexico, and will eventually allow more satisfactory interpretations on a global basis. (Author).

275 PORTER, S. C., STUVIER, M., and HEUSSER, C. J. 1984. "Holocene Sea-Level Changes Along the Strait of Magellan and Beagle Channel, Southernmost South America," Quaternary Research, Vol 22, pp 59-67.

Radiocarbon-dated marine sediments from five coastal sites along the Strait of Magellan and Beagle Channel in southernmost Chile permit construction of a curve of relative sea-level fluctuations during the Holocene. Morphologic and stratigraphic data point to coastal submergence during the early Holocene as the sea rose to a maximum level at least 3.5 m higher than present about 5000 year ago. Progressive emergence then followed during the late Holocene. Data from widely separated localities define a smooth curve, the form of which is explainable in terms of isostatic and hydroisostatic deformation of the crust resulting from changing ice and water loads. Apparently anomalous data from one site located more than 100 km behind the outer limit of the last glaciation may reflect isostatic response to deglaciation. The sea-level curve resembles one derived by Clark and Bloom (1979) (Modified Abstract).

276 POSAMENTIER, H. W., JERVEY, M. T., and VAIL, P. R. 1988. "Eustatic Controls on Clastic Deposition I - Conceptual Framework,' Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 109-124.

A conceptual framework for understanding the effects of eustatic control on depositional stratal patterns is presented. Eustatic changes result in a succession of systems tracts that combine to form sequences deposited between eustatic-fall inflection points. Two types of sequences have been recognized: (1) a type 1 sequence, which is bounded at the base by a type 1 unconformity and at the tippee by either a type 1 or type 2 unconformity and has lowstand deposits at its base, and (2) a type 2 sequence, which is bounded at the base by a type 2 unconformity and at the top by either a type 1 or type 2 unconformity and has no lowstand deposits. Each sequence is composed of three systems tracts; the type 1 sequence is composed of lowstand, transgressive-, and highstand systems tract, and the type 2 sequence is composed of shelf-margin, transgressive, and highstand systems tracts. The type 1 sequence is associated with stream rejuvenation and incision at its base, whereas the type 2 sequence is not.

Eustacy and subsidence combine to make the space available for sediment to fill. The results of this changing accommodation are the onlapping and offlapping depositional stratal patterns observed on basin margins. Locally, conditions of subsidence and/or uplift and sediment supply may overprint but usually will not mask the effects of global sea-level. Any eustatic variation, however, (e.g., irregular eustatic rise or fall, asymmetric fall,

slow or rapid rise or fall, and so on) will be globally effective. The significance of eustatic fall-and-rise inflection points is considered with regard to the occurrence of unconformities are related to rapid eustatic falls, and type 2 unconformities are related to slow eustatic falls. (Authors).

277 **POSAMENTIER, H. W., and VAIL, P. R.** 1988. "Eustatic Controls on Clastic Deposition II - Sequence and Systems Tract Models," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 125-154.

Depositional sequences are composed of genetically related sediments bounded by unconformities or their correlative conformities and are related to cycles of eustatic change. The bounding unconformities are inferred to be related to eustatic-fall inflection points. They are either type 1 or type 2 unconformities, depending on whether sea-level fall was rapid (i.e., rate of eustatic fall exceeded subsidence rate at the depositional shoreline break) or slow (i.e., rate of eustatic fall was less than subsidence rate at the depositional shoreline break). Each sequence is composed of a succession of systems tracts. Each systems tract is composed of a linkage of contemporaneous depositional systems. Four systems tracts are recognized: lowstand, transgressive, highstand and shelf margin. The lowstand systems tract is divided into two parts: lowstand fan followed by lowstand wedge, where the basin margin is characterized by a discrete physiographic shelf edge, or lower followed by upper wedge, where the basin is characterized by a ramp physiography. Two sequence composed of shelf-margin, transgressive-, and highstand systems tracts.

Type 1 and type 2 unconformities are each characterized by a basinward shift of coastal onlap concomitant with a cessation of fluvial deposition. The style of subaerial erosion characterizing each unconformity is different. Type 1 unconformities are characterized by stream rejuvenation and incision, whereas type 2 unconformities typically are characterized by widespread erosion accompanying gradual denudation or degradation of the landscape. Stream rejuvenation and incision are not associated with this type of unconformity. On the slope and in the basin, type 1 unconformities typically are overlain by lowstand fan or lowstand wedge deposits, whereas type 2 unconformities are overlain by shelf margin systems tract deposits. Within incised valleys on the shelf, type 1 unconformities are overlain by either fluvial (lowstand wedge) or estuarine (transgressive) deposits. Within incised valleys on the shelf, type 1 unconformities typically are characterized by a changes in parasequence standing pattern from progradational to aggradational.

Timing of fluvial deposition is also a function of eustatic change insofar as global sea-level is the ultimate base level to which streams will adjust. The elevations of stream equilibrium profiles are affected by eustatic change, and, assuming constant sediment supply, streams will aggrade or degrade in response to eustatically induced shifts in these profiles. Fluvial deposition occurs at different times in type 1 and type 2 sequences and is characterized by different geometries within each type of sequence. In

type 1 sequences, fluvial deposits occur as linear, incised-valley fill during the time of lowstand wedge and transgressive deposition. Fluvial deposits also may occur during highstand deposition as more widespread floodplain deposits within the late highstand systems tract. Fluvial deposits in type 2 sequences are usually limited to widespread floodplain deposits occurring within the late highstand systems tract. (Authors).

278 PUNNING, Ya. M. 1987. "Holocene Eustatic Oscillations of the Baltic Sea-Level," Journal of Coastal Research, Vol 3, No. 4, pp 505-513.

Geochronological, biostratigraphic and geomorphological researches have been used to refine the Holocene northern Baltic territories of the USSR. The Baltic Sea coast over this epoch has been characterized by neotectonic movements, so that without knowledge of relationships between vertical movement rates of crustal motion and eustatic oscillations it is difficult to conduct interregional correlations. To determine the eustatic curve for the Baltic the author assumed the rate of long-term (inherited) vertical movements in the past 10,000 years to be constant, and on this basis glacioisostatic uplift gradients. In the early and middle Holocene time there are four transgressive/ regressive cycles (9,700-9,000, 9,000-7,900, 7,900-6,700, and 6,700-5,600 ^{14}C year BP) have been identified which can be correlated with the Yoldia, Ancylus and two Littorina stages. The height of the Ancylus and two Littorina stages. The height of the Ancylus Lake level was nearly 16 m above the world ocean level. The proposed eustatic curve for the Baltic is used to make interregional correlations. (Author).

279 QUINLAN, G., and BEAUMONT, C. 1981. "A Comparison of Observed and Theoretical Postglacial Relative Sea-Level in Atlantic Canada," Canadian Journal of Earth Sciences, Vol 18, pp 1146-1163.

Two extreme models of late Wisconsinan ice cover in Atlantic Canada and the northeastern U.S.A. are shown to produce postglacial relative sea-level curves that bracket existing field observations at six sites throughout the region. This suggest that the true late Wisconsinan ice distribution is probably intermediate to the two contrasting reconstructions proposed. Both ice models predict the existence of four relative sea-level zones: an innermost zone closest to the center of glaciation in which relative sea-level falls continuously throughout postglacial time; an outermost zone in which it rises continuously; and two transitional zones in which it first falls and then rises in varying proportions according to the distance from the ice margin. The distinctive forms of the relative sea-level curves are probably representative of each of the zones and are unlikely to be significantly perturbed even by large local ice readvances. They, therefore, establish patterns with which future field data are expected to conform. The form that the geological record of relative sea-level change is likely to take within each zone is discussed and promising settings for the collection of new data are proposed. The common practice of separating relative sea-level into an isostatic and a eustatic component is analyzed and shown to be incorrect as usually applied. The practice is also shown to be unnecessary because the models discussed in

this paper predict changes in relative sea-level that can be compared directly with the observations. (Authors).

280 QUINLAN, G., and BEAUMONT, C. 1982. "The Deglaciation of Atlantic Canada as Reconstructed From the Postglacial Relative Sea-Level Record," Canadian Journal of Earth Sciences, Vol 19, No. 12, pp 2232-2246.

The post-Wisconsinan relative sea-level record from Atlantic Canada is used to reconstruct the morphology of late Wisconsinan age ice cover during its retreat from the Atlantic region. The proposed reconstruction has little or no grounded ice in the southern Gulf of St. Lawrence, an ice dome over the north shore of the St. Lawrence, and thin ice, often less than 1 km thick, over much of the rest of the area. A sensitivity analysis shows that the proposed reconstruction is not unique in its ability to account for the relative sea-level record but that the thickness of ice in any individual area of the reconstruction is unlikely to be in error by more than a factor of two. The exact position of the ice margin in some areas is not well constrained by the model; an example is in southeastern Newfoundland.

The numerical model used to relate ice morpholoby to postglacial relative sea-level assumes that the ice sheets are isostatically equilibrated at the glacial maximum and, therefore, that load changes associated with earlier ice-sheet growth may be ignored. This assumption is shown to be reasonable. The same rapid relaxation of the Earth that allows one to ignore the effects of glacial accumulation, however, prohibits one from recognizing the effects of large-scale ablation that may have occurred prior to the assumed glacial maximum. For this reason the proposed reconstruction may be representative of only a late stage in the ablation of much more extensive and thicker ice sheets.

Surfaces of relative sea-level are presented for Atlantic Canada at various times in the past. These surfaces coincide with observational data where such data exist and are felt to provide reasonable estimates of relative sea-level at all other locations for at least the last 13,000 years. (Authors).

281 RAMAN, C. R. V., and MALIEKAL, J. A. 1985. "A Northern Oscillation Relating Northern Hemispheric Pressure Anomalies and the Indian Summer Monsoon," Nature, Vol 314, pp 430-432.

Analysis of the causes of the Indian monsoon have concentrated on climatological phenomena in the southern hemisphere such as El Niño and the Southern Oscillation. By contrast, we have examined meteorological records for the northern hemisphere (0° -180°) spanning much of this century. We find that zonally-integrated mean sea-level pressure anomalies across Eurasia during January to April exhibit a statistically significant negative correlation between values for higher and subtropical latitudes. We further find that there is an association between above-normal activity of the Indian monsoon and a steep poleward-directed pressure anomaly gradient, which tends to persist through the summer and may indicate a strong zonal flow in the circumpolar westerlies. On the other hand, when this pressure anomaly gradient

reverses, zonality is disturbed and the Indian monsoon tends to be drier than usual. Under these conditions, the circumpolar flow becomes persistently meridional as a result of a predisposition to blocking and splitting of the jet. (Authors).

282 RAMANATHAN, V. 1988. "The Greenhouse Theory of Climate Change: A Test by an Inadvertent Global Experiment," Science, Vol 240, pp 293-299.

Since the dawn of the industrial era, the atmospheric concentrations of several radiatively active gases have been increasing as a result of human activities. The radiative heating from this inadvertent experiment has driven the climate system out of equilibrium with the incoming solar energy. According to the greenhouse theory of climate change, the climate system will be restored to equilibrium by a warming of the surface troposphere system and a cooling of the stratosphere. The predicted changes, during the next few decades, could far exceed natural climate variations in historical times. Hence, the greenhouse theory of climate change has reached the crucial stage of verification. Surface warming as large as that predicted by models would be unprecedented during an interglacial period such as the present. The theory, its scope for verification, and the emerging complexities of the climate feedback mechanisms are discussed. (Author).

283 RAMPINO, M. R., and SANDERS, J. E. 1980. "Holocene Transgression in South-Central Long Island, New York," Journal of Sedimentary Petrology, Vol 50, No. 4, pp 1063-1080.

The Holocene history of south-central Long Island and the adjacent inner continental shelf, as recorded in the stratigraphy of transgressive deposits, was studied, using information obtained from more than 400 boreholes, cores and marsh probings in the barrier and backbarrier areas and vibracores and numerous seismic-reflections and bathymetric profiles on the inner shelf. A sequence of deposits which records the Flandrian transgression is preserved in the backbarrier areas of south-central Long Island. The vertical sequence of these transgressive deposits was produced by the movement of successive environments of coastal deposition landward and upward with the rising sea. The vertical sequence is as follows reading from bottom to top: the buried Pleistocene surface, brackish to salt-marsh peat, open-lagoonal silty clays, backbarrier sands, backbarrier-fringe salt-marsh peat, and barrier island sands. The entire transgressive sequence forms a lens-shaped deposit. In going seaward from the mainland shore to the barriers, the sequence thickens from 0 to 10 m; seaward of the barriers the sequence becomes thin again. In places beneath the barrier islands, the transgressive sequence has been completely reworked by the lateral migration of tidal inlets.

Radiocarbon dating of basal peat and organic silty clays has provided a chronology of relative sea-level rise on the southern Long Island coast for the past 8000 years. Relative sea-level on the Long Island coast is interpreted to have been rising at about 2.5 $mm\text{-}year^{-1}$ between 7,000 and 3,000 year B.P. and slowed markedly to about 1 $mm\text{-}year^{-1}$ during their last 3,000 years. Prior to 7,000 year B.P. the rate of submergence may have been as high as 5 $mm\text{-}year^{-1}$.

The extensive preservation of backbarrier sediments, dated between 7,000 and 8,000 year B.P., on the inner shelf of southern Long Island suggests that the barriers have not retreated by continuous shoreface erosion alone but have also undergone discontinuous retreat by in-place "drowning" of barriers and stepwise retreat of the surf zone landward. This would have locally prevented the backbarrier sediments from being reworked and thus would lead to their preservation on the inner shelf. (Authors).

284 **RAMPINO, M. R., and SANDERS, J. E.** 1981a. "Episodic Growth of Holocene Tidal Marshes in the Northeastern United States: A Possible Indicator of Eustatic Sea-Level Fluctuations," Geology, Vol 9, pp 63-67.

Development of coastal marshes during the Holocene submergence of the northeastern United States seems to have been episodic. Radiocarbon dating of the modern marshes indicates that they were generally established within the past 3,000 year. Initiation of marsh growth was probably related to the marked slowing in the submergence rate that took place in the area about 3,000 to 4,000 year ago. On the basis of the few available dates of marsh peats from the inner continental shelf, we suggest that previous episodes of marsh growth took place at about 4,700, 5,600, 6,600, 7,700, 8,200, and 8,600 radiocarbon year ago. These times of marsh growth seem to coincide with proposed times of negative sea-level oscillations, cool climate, and glacial advances. If these oscillations of sea-level are climatically controlled, then the data suggest an approximately 1,000-year cycle of climatic change. (Authors).

285 **RAMPINO, M. R. and SANDERS, J. E.** 1981b. "Evolution of the Barrier Islands of Southern Long Island, New York," Sedimentology, Vol 28, pp 37-47.

Three lines of evidence based on data from more than 400 boreholes and vibrocores have been used to reconstruct the evolution of the barrier islands during the Holocene transgression in southern Long Island, New York: (1) the Holocene transgressive stratigraphic sequence behind the present barrier, (2) the stratigraphic patterns of the inner shelf, and (3) the morphology of the now-buried late Pleistocene coastal features.

The extensive preservation of backbarrier sediments, radiocarbon dated between 7,000 and 8,000 year B.P., on the inner shell of southern Long Island suggests that the barriers have not retreated by continuous shoreface erosion alone, but have also undergone discontinuous retreat by in-place 'drowning' of barriers and stepwise retreat of the surf zone. Such stepwise retreat of the surf zone has prevented the backbarrier sediments from being reworked.

Based on the presence of submerged barrier sand bodies in seismic records, it is inferred that about 9,000 years ago, when the sea stood about 24 m below the present sea-level, a chain of barriers developed on the present shelf about 7 km offshore of the present barriers. With continued sea-level rise, the -24 m barrier built upward until the sea reached about -15 m MSL, just prior to 7,000 year B.P. The barriers were then submerged by the rapidly rising sea, and the surf zone shifted rapidly landward to a position about 2 km from the present shoreline. The surf zone overstepped to the landward

margin of the old lagoon, which had become fixed at the steep seaward face of mid-Wisconsinan (?) or Sangamonian coastal barriers. During the past 5,000 or 6,000 years, the shoreface has retreated continuously by about 2 km.

Evidence from southern Long Island and elsewhere in regions of coastal submergence indicates that rapid sea-level rise and low sand supply seem to favor the stepwise retreat of barriers, whereas slow rates of submergence and a greater supply of sand generally favor continuous shoreface retreat. Stationary upbuilding, or seaward progradation of barriers may occur when supply of sand is great, and/or submergence is slowed or reversed. Morphologic highs on the pretransgression surface (such as old barrier ridges) tend to fix the migrating barrier shoreline during either continuous retreat, or stepwise retreat of barriers. (Authors).

286 RAMSEY, K. E., MOSLOW, T. F., and PENLAND, S. 1985. "Sea-Level Rise and Subsidence in Coastal Louisiana," In Association of State Floodplain Managers, 9th Meeting.

The major impact of relative sea-level (RSL) in Louisiana is: 1) land loss within the wetlands and marshes and 2) erosion of beaches and barrier islands along the shoreline. However, the exact role sea-level rise plays in the nature and severity of land loss and coastal erosion remains unresolved. This question is most important to wetland managers and coastal planners in assessing the future existence of southern Louisiana's coastal zone.

A number of depositional environments are represented within the 26 million sq. km of coastal wetlands in southern Louisiana. The most common environments are the coastal marshes which account for 40% of all coastal wetlands in the United States (Gosselink, 1980; Davis, 1983). The coastal wetlands are flat, low lying areas with average elevations of less than 1 m and are being converted to open water bays or lagoons at a progressive geometric rate exceeding 101 sq. km per year (Gagliano et al, 1981). Louisiana faces the most critical barrier shoreline erosion problem in the United States due to relative sea-level rise upon which storms and man's activities are superimposed accelerating the problem (Penland and Boyd 1982). (Introduction).

287 RAMSEY, K.E., and MOSLOW, T.F. 1987. "A Numerical Analysis of Subsidence and Sea-Level Rise in Louisiana," Proceedings of Coastal Sediments '87, Vol 2, pp 1673.

An analysis of historical water level records from 78 tide gage stations and 550 km of geodetic leveling data has documented the spatial and temporal variations in the recent history (1942-1982) of relative sea-level rise and compactional subsidence in coastal Louisiana. Yearly means for the rate of relative sea-level rise were calculated for tide gage stations with continuous daily records from 1942 to 1982. An average rate for the entire statewide region of 0.85 cm/year was determined. For the same time period, this regional rate is 3.7 times greater than the assumed Gulf of Mexico eustatic sea-level rise rate of 0.23 cm/year, and 5.7 times greater than the estimated observed global rise rate of 0.15 cm/year. Statewide sea-level rise rates were calculated at 0.45 cm/year during 1942-1962, and 1.12 cm/year during

1962-1982, suggesting that the sea-level rise rate has been 2.5 times greater in the last 20-year epoch.

Segregating tide gage stations into seven hydrographic basins reveals a great variation in sea-level rise both temporally and spatially throughout Louisiana. The greatest rates of rise are observed along the coast(1.0-1.2 cm/year) and in the southwestern portion of the Louisiana deltaic plain (1.8-1.9 cm/year). In most cases, there is a gradual decrease in the rate of rise landward from the coastline and in the areas distal to the deltaic plain (Pontchartrain Basin and Chenier Plain). Compactional subsidence accounts for approximately 80% of the observed sea-level rise in Louisiana based on the eustatic correction of 0.23 cm.year for the Gulf of Mexico.

An analysis of geodetic leveling data documents the role of differential subsidence due to sediment compaction and loading in accounting for the observed spatial variations in relative sea-level rise. Subsidence has been greatest on the western deltaic plain (0.36 cm/year) and along the coast (1.03 cm/year), with a marked decrease landward from the coast and distal from the axis of the Pleistocene Mississippi alluvial valley. A time sequence analysis of leveling data documents an increase in the rate of subsidence since 1955.

The results of this study suggest that the rapid rates of land loss and coastal erosion experienced in many areas of southern Louisiana are due to factors other than eustatic sea-level rise and compactional subsidence. A decreased sediment supply seems most important and, along with diversions of rivers and streams, probably explains the dramatic increases observed over the past 25 years. (Authors).

288 **RASMUSSEN, R. A. and KHALIL, A. K.** 1986. "Atmospheric Trace Gases: Trends and Distributions Over the Last Decade," Science, Vol 232, pp 1623-1624.

Concentrations of the halocarbons CCl_3 (F-11), Ccl_2F_2 (F-12), Ccl_4, and CH_3CCl_3, methane (CH_4), and nitrous oxide (N_2O) over the decade between 1975 and 1985 are reported, based on measurements taken every January at the South Pole and in the Pacific Northwest. The concentrations of F-11, F-12, and CH_3CCl_3 in both hemispheres are now more than twice their concentrations 10 years ago. However, the annual rates of increase of F-11, F-12, and CH_3CCl_3 are now considerably slower than earlier in the decade, reflecting in part the effects of a ban on their nonessential uses. Continued increases in these trace gas concentrations may warm the earth and deplete the stratospheric ozone layer, which may cause widespread climatic changes and affect global habitability. (Authors).

289 **REBERT, J. P., DONGUY, J. R., ELDIN, G., and WYTKI, K.** 1985. "Relations Between Sea-Level, Thermocline Depth, Heat Content, and Dynamic Height in the Tropical Pacific Ocean," Journal of Geophysical Research, Vol 90, No. C6, pp 11719-11725.

The use of combined information from expendable bathythermograph and sea-level observations for ocean monitoring requires the establishment of relations between sea-level, thermocline depth, heat content, and dynamic

height. Sea-level fluctuations are a good measure of thermocline depth fluctuations in the tropical Pacific between about 15° N and 15° S and allow the determination of changes of upper-layer volume. Sea-level is also a good measure of heat content, and useful correlations extend to higher latitudes. Dynamic height and sea-level fluctuations agree only in those areas where the thermal structure resembles a two-layer system very well, and good correlations are restricted to a narrower area. The combination of bathythermograph and sea-level observations will allow a better mapping of the changes of thermocline topography, heat content, and dynamic height for the monitoring of climatic changes in the tropical Pacific. (Authors).

290 REDFIELD, A. C. 1967. "Postglacial Change in Sea-Level in the Western North Atlantic Ocean," Science, Vol 157, No. 3789, pp 687-692.

Radioactive carbon determinations of the age of peat indicate that at Bermuda, southern Florida, North Carolina, and Louisiana, the relative sea-level has risen at approximately the same rate, 2.5×10^{-3} ft per year (0.76×10^{-3} m per year), during the past 4,000 years. It is proposed tentatively that this is the rate of eustatic change in sea-level. The rise in sea-level along the northeastern coast of the United States has been at a rate much greater than this, indicating local subsidence of the land. Between Cape Cod and northern Virginia, coastal subsidence of 13 ft appears to have occurred between 4,000 and 2,000 years ago and has continued at a rate of about 1×10^{-3} ft per year since then. On the northeastern coast of Massachusetts, subsidence of 6 ft occurred between 4,000 and 3,000 years ago; since then sea-level has risen at about the eustatic rate. Between 12,000 and 4,000 years ago, sea-level rose at an average of about 11×10^{-3} ft per year. The part played by local subsidence of temporary departures from the average rate during this period is uncertain. (Authors).

291 REILIENGER, R. 1987. "Re-analysis of Crustal Warping in Coastal Maine," Geology, Vol 15, pp 958-961.

Investigation of leveling-circuit misclosures indicates the presence of an uncorrected systematic error in one of the critical surveys previously used to define rapid contemporary subsidence of easternmost Maine relative to points farther inland; however, the average rate of subsidence is reduced from 9 mm/year, reported by Anderson et al., to about 1-2 mm/year. This rate is similar to that derived from the Eastport, Maine, tide gage, assuming a 1.0-1.5 mm/year "eustatic" rise in sea-level. In addition, a subsidence rate of 1-2 mm/year is roughly consistent with longer term (a few thousand years) rates derived from glacial-marine deltas and from dated basal peats along the Maine coast. (Author).

292 **REVELLE, R.** 1982. "Carbon Dioxide and World Climate," Scientific American, Vol 247, No. 2, pp 36-43.

Three issues of carbon dioxide effects are examined in this paper:
(1) how much and at what rate carbon dioxide will be added to the atmosphere,
(2) what the global rise in temperature would be in the various regions, and
(3) the human impact of increased concentrations of carbon dioxide and other trace gases. (Gorman).

293 **RHEA, S.** 1989. "Evidence of Uplift Near Charleston, South Carolina," Geology, Vol 17, pp 311-315.

In spite of extensive research, the causal structure of the 1886 magnitude 7 earthquake near Charleston, South Carolina, has not been identified. In this study, I analyzed digital surface topography and river morphology in light of earlier studies using seismic reflection, seismic refraction, earthquake seismology, and gravity and magnetic surveys. This analysis revealed and area approximately 400 km^2 northwest of Charleston that may have been repeatedly uplifted by earthquakes. Geologic and seismic reflection data confirm alteration of formations at depth. Deformation of the surface is supported by observations on aerial and LANDSAT photographs. Therefore, the structure on which the 1886 earthquake occurred may be within the uplifted area defined in this report. (Author).

294 **RICHARDS, G. W.** 1985. "Fossil Mediterranean Mollusks as Sea-Level Indicators," Geological Magazine, Vol 122, No. 4, pp 373-381.

Intertidal mollusks are known to occur in similar positions or zones on shores throughout the world. However, little is known about the extent to which these distributions are preserved in the fossil record. This study attempts to define the relationship to present sea-level of live and dead intertidal mollusks in the Mediterranean, and utilizes this information to interpret the position at which Quaternary shorelines were formed.

The preservation of zonation patterns in the fossil record is affected by post-mortem transport, breakage and burial of the shell material. To take account of such taphonomic changes, experimental studies of shell transport and burial under waves and unidirectional currents were made, and the distribution of dead mollusks on modern shores were compared with live distributions. It proved possible to predict the frequency with which certain species were deposited on the modern shore and, by analogy, the likelihood of their preservation in the fossil record. Thus death assemblages in fossil shorelines can be accurately related to past sea-levels. (Author).

295 RIENECKER, M. M. and MOOERS, N. K. 1986. "The 1982-1983 El Niño Signal Off Northern California," Journal of Geophysical Research, Vol 90, No. C5, pp 6597-6608.

The major El Niño event of 1982-1983 affected the entire California Current system. The anomalous conditions along the west coast of North America were related to the equatorial anomalies and also to the anomalous atmospheric circulation in the Northeast Pacific, where the Aleutian Low was east of its usual position and the associated 700-mbar height reached its lowest value on record in February-March 1983. Positive temperature and negative salinity anomalies in the upper ocean, extending from the coast to at least 200 km offshore, were reported from San Diego to Vancouver Island. In data acquired in domains centered approximately 180 km off northern California by the Ocean Prediction Through Observation, Modeling and Analysis Program, anomalies in both temperature and salinity were most pronounced subsurface. Spatially and monthly averaged temperatures were about 3° C warmer than normal at 80 to 100 m in April and again in December 1983. At 100 to 120 m, salinity was about 0.4 parts per thousand lower than normal in July 1983 and July 1984, several months later than the temperature anomaly maxima. The temperature anomalies may be related to the poleward propagation of the equatorial El Niño perturbation by coastally trapped waves, with offshore propagation by planetary Rossby waves possibly playing some role in the relaxation of the perturbed eastern boundary current circulation. Anomalous onshore advection associated with the perturbed atmospheric circulation, deeper than normal mixed layers, or depression of the thermocline and halocline by the passage of Rossby waves could each account for coincident positive temperature and negative salinity anomalies. (Authors).

296 RODEN, G. J. 1966. "Low-Frequency Sea-Level Oscillations Along the Pacific Coast of North America," Journal of Geophysical Research, Vol 71, No. 20, pp 4755-4776.

The information obtainable from monthly mean sea-level records and the joint variation of sea-level, atmospheric pressure, and sea temperatures are analyzed. The spectrum of sea-level is time invariant and shows significant peaks only at frequencies corresponding to the annual and semiannual oscillations. The bispectrum of sea-level indicates a weak interaction of the annual frequency with itself, as well as with other frequencies. Secular sea-level changes along the Pacific coast are related to land subsidence and uplift. The mean duration of positive and negative sea-level anomalies from long-term monthly means is of the order of 3 months. Extreme durations vary between 10 and 34 months and are closely related to large-scale atmospheric disturbances. The areal coherence of nonperiodic sea-level fluctuations is of the order of 1,200 km. At temperate and high latitudes there is good coherence between nonperiodic sea-level and atmospheric pressure oscillations. The response between these two variables varies from -0.9 cm/mb to -2.3 cm/mb in the frequency range between 1 and 6 cycles per year. The coherence between nonperiodic sea-level and sea temperature fluctuations is high in tropical latitudes and low in polar latitudes. The response is largely independent of frequency, varying from 1.0 to 2.7 cm/° C. These findings are in agreement

with the coefficient of thermal expansion of seawater and the depth of the mixed layer. (Author).

297 **ROOS, M., and GRAVENHORST, G.** 1984. "The Increase in Oceanic Carbon Dioxide and the Net CO_2 Flux. into the North Atlantic," Journal of Geophysical Research, Vol 89, No. C5, pp 8181-8193.

In the present work the differences between the pCO_2 in the sea surface water and the atmospheric CO_2 mixing ratio were determined on the basis of measurements of Meteor expedition 32 in the North Atlantic in 1973. These Meteor measurements were complemented by a compilation of CO_2 data that has been available to us on the North Atlantic since the beginning of this century. A thorough evaluation of these data shows that, like the increase of the CO_2 mixing ratio in the atmosphere, there is also a general increase of PCO_2 in the surface water of the North Atlantic. Although the CO_2 differences across the air-sea interface have been measured by various methods since 1903, they can still be compared and, at the same time, be used to derive their geographical distribution on the North Atlantic. Based on these data, net CO_2 fluxes of 0.16×10^{15} g C a^{-1} from the atmosphere into the North Atlantic between the equator and 40° N and of 0.45×10^{15} g C a^{-1} north of 40°N are derived. The total net CO_2 uptake of 0.6×10^{15} g C a^{-1} corresponds to 13% of the present global industrial CO_2 emission per year. (Authors).

298 **ROSEN, P. S.** 1978. "A Regional Test of the Bruun Rule on Shoreline Erosion," Marine Geology, Vol 26, pp M7-M16.

Sea-level rise has been quantitatively related to shoreline retreat by the Bruun Rule. This relationship was verified on a field scale along the 336-km shoreline on the Virginia Chesapeake Bay. Relative sea-level rise in this area is as high as 5.43 mm/year, and mean longterm shore retreat is 0.98 m/year.

The model was applied individually to 146 beach units in the area, and the results were compiled regionally. This long-term, regional setting where seasonal or local variations in process are averaged out, is believed to be the context in which the model has physical meaning.

The erosion rate predicted by the Bruun Rule fits the long-term measured rate with a 3% error. The fit of the Bruun Rule for the Virginia Chesapeake Bay shoreline system demonstrates that sea-level rise can account for all shore retreat in the system. (Author).

299 **ROSEN, P. S.** 1980. "An Application of the Bruun Rule in the Chesapeake Bay," Proceedings of the Per Bruun Symposium, Newport, Rhode Island, International Geographical Union Commission on the Coastal Environment, Bureau for Facility Research, Western Washington University, Bellingham, Washington, pp 55-62.

This application of the Bruun Rule (Bruun, 1962) was part of a regional study of the erodability of the Virginia Chesapeake Bay Shoreline (Rosen, 1978). The study area consists of 350 km of estuarine shoreline in the

southern half of the Chesapeake Bay (Fig. 1). Although fetch restrictions result in a low to moderate energy wave climate (Rosen, 1976), there is an extremely high and variable erosion rate (x = 0.94 m/year, Fig. 2). The Bruun Rule was utilized to determine how much of this erosion can be accounted for by the rise in sea-level. (Introduction).

300 **ROSS, C. A. and ROSS, J. R. P.** 1988. "Late Paleozoic Transgressive-Regressive Deposition," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., <u>Sea-Level Changes: An Integrated Approach</u>, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 227-248.

Approximately sixty transgressive-regressive depositional sequences are present in Carboniferous and Permian shallow-marine successions on the world's stable cratonic shelves. These sequences were synchronous depositional events that resulted from eustatic sea-level changes. Based on currently available age correlations of rapidly evolved late Paleozoic tropical, subtropical, and temperate shelf faunas, the sequences on different cratonic shelves were time equivalent. These transgressive-regressive sequences averaged about 2 million years and ranged from 1.2 to 4.0 million years in duration.

Local depositional conditions are important in controlling sedimentary patterns on different cratonic shelves. These conditions are affected by changes in sea-level, strandline position, and drainage base level and are reflected in the sedimentary record. Because midsize sea-level fluctuations are usually widely identifiable in the stratigraphic record, they are useful aids in correlation. They are particularly helpful between regions that have contrasting depositional conditions, such as between a carbonate shelf starved of clastic sediments and a clastic-dominated shelf on which carbonates are rare.

The appearance of new species and generally occurs above unconformities that signal new marine transgressive events and new depositional sequences. The durations of the hiatuses between these transgressive-regressive sequences are difficult to estimate. The hiatuses may represent cumulatively as much time, if not more, than the rock record. The numerous worldwide synchronous unconformitites marking hiatuses of considerable duration within late Paleozoic shelf strata suggest that the fossil record may be very incomplete an preserves mostly biota that were extant during times of high sea-level. Such an incomplete fossil record could easily be misinterpreted as a punctuated evolution having a highly irregular mutation rate. (Authors).

301 **ROSSITER, J. R.** 1960. "Report on the Reduction of Sea-Level Observations (1940-1958) for R.E.U.N.: Permanent Service for Sea-Level," Liverpool, England, pp 24.

On the occasion of the R.E.U.N. Meeting at Liverpool in October, 1959, the Permanent Service for Mean Sea-level (MSL) was requested by the R.E.U.N. Commission to investigate further the possibilities of oceanographic levelling around the European coastline.

In papers submitted by oceanographers to the Liverpool meeting four main factors affecting MSL were emphasized; wind and atmospheric pressure, sea water density, the nodal tide and secular variations. The present investigation has been concerned in detail with all these factors except the effect of sea water density. (Introduction).

302 **RUDDIMAN, W. F., and MCINTYRE, A.** 1981. "Oceanic Mechanisms for Amplification of the 23,000 Year Ice-Volume Cycle," Science, Vol 212, No. 4495, pp 617-627.

Situated adjacent to the largest Northern Hemisphere ice sheets of the ice ages, the mid-latitude North Atlantic Ocean has an important role in the earth's climate history. It provides a significant local source of moisture for the atmosphere and adjacent continents, forms a corridor that guides moisture-bearing storms northward from low latitudes, and at times makes direct contact along its shorelines with continental ice masses. Evidence of major ice-ocean-air interactions involving the North Atlantic during the last 250,000 years is summarized. Outflow of icebergs and meltwater initially driven by summer insolation over the ice sheets affects mid-latitude ocean temperatures, summer heat storage, winter sea-ice extent, and global sea-level. These oceanic responses in turn influence the winter moisture flux back to the ice sheets, as well as ablation of land ice by calving. Spectral data indicate that the oceanic moisture and sea-level feedbacks, in part controlled by glacial melt products, amplify Milankovitch (insolation) forcing of the volumentrically dominant mid-latitude ice sheets at the 23,000-year precessional cycle. (Authors).

303 **RUFFMAN, A., MILLER, A. A. L., and SCOTT, D. B.** 1985. "Holocene Rise of Relative Sea-Level at Sable Island, Nova Scotia, Canada: Correction and Note," Geology, Vol 13, pp 661-663.

The map provided in Scott et al. (1984) showing the three 1981 boreholes on Sable Island is incorrectly drawn. The borehole locations are shown correctly on the published map relative to the various geographical features of the island, but they are shown incorrectly with respect to the geographical grid. If the geographical coordinates of the three boreholes are determined and digitized from the map provided in the paper and then plotted on the most current bathymetric map, all three boreholes plot well out in the ocean to the south of the island. Sable Island has a reputation for minor shifts in its shoreline at the spits, but it has not shifted to such a degree in the past few years as to put any of the original, onshore borehole locations into the offshore area at the present time. (Authors).

304 **RUSSELL, R. J.** 1957. "Instability of Sea-Level," American Scientist, Vol 45, pp 414-430.

On a five-ft globe the vertical relief between the highest summit on land and the most profound deep of the ocean would approximate 0.09 inch. The depth to the main floor of the Pacific Ocean would be barely discernible, at a depth of about 0.02 inch below the surface of the geoid. The vertical relief along any great circle will be included within the most perfect possible circle having a five-ft diameter if the line has sufficient width to be visible a few ft away. The ocean basins have thus about the same outward convexity as the earth's surface.

In the traditional terminology of the geologist, the lithosphere is in part separated from the atmosphere by a hydrosphere which is essentially similar in shape to a thin membrane which might be thought of as covering a spherical balloon. The hydrosphere is interrupted in continuity by dry land, but its oceanic part forms a system that covers somewhat more than 70 percent of the globe.

The boundaries between the hydrosphere and its marginal lands are complex. For the most part they are the shorelines of the world's ocean system, with their many complicated ramifications. While the upper surface of the oceans is regarded as sea-level, the mean position of that level varies considerably from place to place. The radial distance from the earth's center to the mean sea-level lengthens near mountainous coasts, such as western South America, when gravitational pull distorts the ocean surface upward. Sea-level varies temporarily according to tidal forces, barometric pressure, and changes in wind.

Leaving aside the question of departures between geoid and water surface, changes in level between land and sea also depend on other factors. At a given place, mean sea-level can be lowered as a result of subsidence of an area of ocean floor many thousands of miles away. The down-faulting of the trough of an ocean deep produces some minor effect along all coasts of the ocean system. The building of deltas or the deposition of terrigenous sediments around continental and island shores has a basin-filling effect, and hence tends to displace ocean surfaces toward slightly higher levels. During earth history there have been many secular changes such as these which have affected sea-levels enormously, the greatest being volumetric growth of the hydrosphere itself. Our discussion, however is not directed toward these long term changes of level. It will concentrate on problems of more immediate interest and less theoretical nature. It will involve mainly the closing chapter of earth history, the time in which we are now living, including the recent past, with some mention of the immediate future. There have been several notable changes in sea-level during the Quaternary. (Author).

305 SAHAGIAN, D. 1988. "Ocean Temperature-Induced Change in Lithospheric Thermal Structure: A Mechanism for Long-Term Eustatic Sea-Level Change," Journal of Geology, Vol 96, pp 254-261.

Eustatic sea-level change can be produced by a change can be produced by a change in ocean bottom water temperature through an alteration of the upper thermal boundary condition of oceanic lithosphere. The consequent evolution of lithospheric thermal structure can cause thermal expansion or contraction of the lithosphere. If continental lithosphere remains unaffected by the change in ocean temperatures, "eustatic" sea-level will change as measured in the continental frame of reference. A two-dimensional finite difference model

has been formulated and shows that if ocean bottom water temperature were to change rapidly by 14 C, as it may have during the Tertiary, sea-level would change by 8 m in 8 million years, and 17 m in 40 million years. This result is in agreement with the one-dimensional error function solution for a heating or cooling halfspace. However, the changes in lateral heat flow between ocean water and the continental slope, and between oceanic and continental lithosphere, can produce epeirogenic motions of the continental margins (and thus may represent a climatic control on epeirogenic processes). Thus, the affected margins should not be used as a reference frame against which to measure the magnitude of sea-level change produced by this mechanism. While this mechanism of water temperature-induced change in lithospheric thermal structure produces effects with magnitudes which are less than those of ice volume changes, the effects of the mechanism are relatively simple to calculate and should be included when consideration is made of eustatic sea-level changes in the past. (Author).

306 **SALWEN, B.** 1962. "Sea-Levels and Archaeology in the Long Island Sound Area," American Antiquity, Vol 28, No. 1, pp 46-55.

Two coastal sites on Long Island, the Stony Brook site and the Baxter site, are examined in the light of Fairbridge's data on sea-level fluctuations during the last 7000 years. In each case, the coastline at the time of occupation is reconstructed, and inferences are made about the ecological setting. Archaeological data pertaining to subsistence pattern are then reviewed in the light of the probable local environment at the time of occupation. Orient culture occupations at both sites date from about 2900 B.P., when sea-level is believed to have been about 10 ft below the present level. The Orient component midden at Stony Brook contains more oyster shell than any other species of mollusk, while that at the Baxter site contains a large percentage of clam shell than any other species of mollusk, while that at the Baxter site contains a large percentage of clam shell and almost no oyster. This difference cannot be explained on cultural grounds, but can be shown to reflect local environmental factors existing under conditions of lowered sea-level. The midden contents at other times of occupation are found to be consistent with the corresponding sea-levels. (Modified Abstract).

307 **SARG, J. F.** 1988. "Carbonate Sequence Stratigraphy," Wilgus, C.K., Hastings, B.S., Kendall, C.G., Posamentier, H.W., Ross, C.A., and Van Wagoner, J.C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 155-182.

The major controls on changes in carbonate productivity, as well as platform or bank growth and the resultant facies distribution, are interpreted here to be short-term eustatic changes superimposed on longer term tectonic changes (i.e., relative changes in sea-level). Carbonate platforms associated with sea-level highstands are characterized by relatively thick aggradational-to-progradational geometry. They are bounded below by the top of a transgressive unit and above by a sequence boundary. Two types of highstand

platform, keep-up and catch-up, are differentiated here. (1) A keep-up carbonate highstand platform is interpreted to represent a relatively rapid rate of accumulation that is able to keep pace with periodic rises in relative sea-level. A keep-up carbonate is characterized mounded/oblique stratal configuration at the platform/bank margin and in places on the platform. (2) A catch-up carbonate highstand platform is interpreted to represent a relatively slow rate of accumulation that is characterized by micrite-rich parasequences and pervasive early submarine cementation at the platform margin. A catch-up carbonate displays a sigmoid depositional profile at the platform/bank margin.

At the formation of a type 1 sequence boundary, where the rate of eustatic fall is interpreted to be greater than subsidence at the platform/bank margin, two major processes occur: (1) local-to-regional slope front erosion and (2) subaerial exposure of the shelf and major seaward movement of the regional meteoric lens. At a large-scale type 1 sequence boundary, sea-level may fall from 75 to 100 m or more and for an extended period of time. When this occurs, the meteoric lens becomes established over the shelf for a long time, and its influence extends well into the subsurface. If there is sufficient rainfall and a permeable section with mineralogically unstable grains, significant solution will occur over the shelf in the shallow portion of the underlying highstand carbonate platform. Precipitation of phreatic cements will occur deeper or downdip in the section. At a small-scale type 1 sequence boundary, where sea-level falls less than about 100 m and for a short period of time, the meteoric lens becomes less well established. It remains in a shallow position on the shelf, causing less extensive solution. Mixing and hypersaline dolomitization may be important processes during the late highstand and continuing through the formation of either a large- or small-scale type 1 sequence boundary. At a type 2 sequence boundary, in which the rate of eustatic fall is interpreted to be less than the rate of subsidence at the platform/bank margin, the inner-platform peritidal and outer-platform shoal areas will be exposed. The dominant meteoric effect will be in the inner-platform areas.

During sea-level lowstands, three types of carbonate deposits are recognized: (1) allochthonous material derived from erosion of the slope (i.e., debris sheets and allodapic carbonate sands): (2) autochthonous wedges deposited on the upper slope during type 1 sea-level lowstands; and (3) type 2 platform/bank margin wedges. In addition, given the appropriate climatic and hydrographic conditions (i.e., evaporation exceeds influx, and basin is restricted), evaporite lowstand wedges may occur associated with either type 1 or type 2 sequence boundaries. During evaporitic lowstands, hypersaline dolomitization, evaporite replacement, and solution may occur in associated carbonate highstand platforms. Siliciclastic lowstand deposition will occur in areas where an undip-source terrain is available. (Author).

308 **SCHNEIDER, S. H., and CHEN, P. S.** 1980. "Carbon Dioxide Warming and Coastline Flooding: Physical Factors and Climatic Impact," Annual Review of Energy, Vol 5, pp 107-40.

The purpose of this article is to use quantitative information in assessing climatic impacts. The authors review the basic elements of climatic prediction, potential geographic extent of inundation and the associated economic losses, and social and political impacts. (Gorman).

309 **SCHOFIELD, J. C.** 1975. "Sea-Level Fluctuations Cause Periodic, Post-Glacial Progradation, South Kaipara Barrier, North Island, New Zealand," New Zealand Journal of Geology and Geophysics, Vol 18, No. 2, pp 295-316.

The off-shore region between Mt. Egmont and the Kaipara Harbour entrance forms the off-shore portion of the Egmont-Kaipara Sand System. The late post-glacial input of sand from landward sources into this system is less than 7% of the volume of post-glacial dunes which forms its coastal deposits. The only other source for the dune sand is the sea floor. Hence it is not surprising that the mineralogy of the sea floor and dune sands is the same. Furthermore, five separate periods of progradation are recognized that are correlated with five periods of sea-level fluctuations which have occurred during the post-glacial fall in sea-level from a local maximum of +2·1 m, 4425 years ago. The volume of progradation is approximately proportional to the net fall in sea-level during each fluctuation. Departures from this proportionality are due mainly to insufficient time for equilibrium to be established between sea floor and new sea-level. Sea-level is currently rising and is promoting deposition on the sea floor down to depths of 50 m, beyond which there is a belt of coarser sand down to an average of 100 m. The main movement of sand is between the depth of 50 m and the shore. A wedge of sand from this region with a maximum, near-shore thickness of 2·1 m (the overall post-glacial fall in the sea-level) equals slightly more than the total volume of post-glacial dune sand preserved within the Egmont-Kaipara Sand System. It is concluded that the present sea floor is in partial equilibrium with sea-level, and the local profile of equilibrium probably extends to depths of between 80 and 120 m. (Author).

310 **SCHOLL, D. W.** 1964. "Recent Sedimentary Record in Mangrove Swamps and Rise in Sea-Level Over the Southwestern Coast of Florida, Part I," Marine Geology, Vol 1, pp 344-366.

Beneath the shallowly submerged coastal mangrove forest (paralic mangrove swamps) of southwestern Florida, marine and brackish-water sediments of Recent age overlie fresh water calcitic mud that was deposited on bedrock or fresh-water peat about 4,000 years ago. This sedimentary succession is thought to be the record of a marine inundation of the western margin of the extensive fresh-water swamps (Everglades) of southern Florida. To map the extent of the submergence a stratigraphic study was made of piston core samples of unconsolidated sediments underlying waterways dissecting the coastal forest and intra-forest bays enclosed within it. These cores were primarily taken in

the vicinity of Whitewater Bay and in the Ten Thousand Islands area. The latter region forms the northern end of approximately 50 nautical miles of swamps and coastal mangrove forest; this belt of paralic swamps is typically 1-3 miles broad, although it is as much as 10 miles wide in some areas. Whitewater Bay is situated at the southern terminus of these swamps.

The sequence of transgressive sediments consists of a basal unit of autochthonous (in situ) fibrous peat, largely derived from mangrove and other rooted halophilic plants, and an overlying allochthonous unit of peaty and calcareous shell debris (Whitewater Bay) or shelly quartz-rich sand and silt (Ten Thousand Islands area). Judging from radiocarbon dates, the basal peat unit began to form 3,000-3,400 years ago after cessation of calcitic mud formation. Within a period of a few hundred to a thousand years formation of in situ fibrous peat in area which are now waterways and intra-forest bays gave way to the deposition of shelly brackish-water and marine sediments of the upper member of the transgressive sequence. The environmental shift from fresh-water to brackish-water and marine milieus came about in response to a more or less steady rise in sea-level and marine inundation of former mainland paludal swamps.

Based on the age and elevation of fibrous peat overlying bedrock and fresh-water calcitic sediment, the rise in sea-level across southwestern Florida 3,000-4,000 B.P. stood 9-11 ft. lower; about 3,000 B.P. it stood only 4.5 ft. lower. Since ca. 3,000 B.P. sea-level has risen to its present elevation at a steadily diminishing rate. This is interpreted from the rate of clastic sedimentation during the last three millennia in areas near the seaward edge of the swamps.

Because much geologic and geomorphic evidence attests to the tectonic stability of peninsular Florida since the last interglacial stage, the rise in sea-level is regarded as eustatic in cause and related to post-Valderan melting of continental ice masses. Sea-level has evidently not stood appreciably higher than its present position during the last 5,000 years. This means that the + 10 ft. Silver Bluff shoreline recognized along the eastern coast of the United States, and its equivalent mapped elsewhere in the world, is not a Recent age but probably of Sangamon (last interglacial) or mid-Wisconsinan age. (Author).

311 SCHOLL, D. W., and STUVIER, M. 1967. "Recent Submergence of Southern Florida: A Comparison With Adjacent Coasts and Other Eustatic Data," Geological Society of America, Bulletin 78, pp 437-454.

Submergence data gathered in southern Florida indicate that approximately 4400 years ago (in terms of radiocarbon years) sea-level was about 4 m lower than today's level. Between 4400 and 3500 B.P., sea-level rose at a rate close to 30 cm/100 years (1.0 ft/century). About 3500 B.P., when sea-level stood 1.6 m below its contemporary position, the rate of rise diminished by a factor of five; since 1700 B.P., the rate of rise has averaged only about 3 cm/100 year (0.1 ft/century). Because a considerable body of evidence points to the probable tectonic stability of southern Florida in recent time, the recorded submergence is regarded as a measure of an eustatic change in sea-level.

The Florida submergence curve shows that sea-level has risen more or less steadily to its present level during the last 4400 year. This differs

significantly from the hypothesis that sea-level rose 2-4 m above its present position during this time. The Florida submergence data also do not support a strict interpretation of the stable sea-level hypothesis, i.e., that sea-level reached its present position (and maintained it) sometime between 3000 and 5000 years ago. (Authors).

312 SCHWARTZ, M. 1965. "Laboratory Study of Sea-Level Rise as a Cause of Shore Erosion," Journal of Geology, Vol 73, No. 3, pp 528-534.

In contrast to classic concepts of the relationship of sea-level change to shore erosion, Per Brunn has proposed a new theory giving dimensional relationships to the process. To make a preliminary test of the validity of the theory, a small-scale model study was conducted, using constant beach and wave characteristics under variable conditions of water level rise. Equilibrium was rapidly established with erosion and deposition taking place as predicted by Brunn. (Author).

313 SCHWARTZ, M. L. 1967. "The Brunn Theory of Sea-Level Rise as a Cause of Shore Erosion," Journal of Geology, Vol 75, No. 1, pp 76-92.

Laboratory and field tests have been undertaken in order to test the new theory proposed by Brunn which offers dimensional relationships to the process of sea-level rise as a cause of shore erosion, in contrast to the classic Johnsonian concept. Brunn holds that when an equilibrium profile is developed, (a) there is a shoreward displacement of the beach profile as the upper beach is eroded, (b) the material eroded from the upper beach is equal in volume to the material deposited on the nearshore bottom, (c) the rise of the nearshore bottom as a result of this deposition is equal to the rise in sea-level, thus maintaining a constant water depth in that area.

In field investigations, the variation between neap and spring low tide was utilized as a short-term model of sea-level rise in obtaining profiles on two small-scale wave basins in coordination with the beach surveys. First order determinations, based on combined field and laboratory data, affirm the Brunn theory of predictable shore erosion following a rise in sea-level. (Author).

314 SCHWARTZ, M. L. 1972. "Seamounts as Sea-Level Indicators," Geological Society America Bulletin, Vol 83, pp 2975-2980.

Terraces on Cobb and Bowie Seamounts, with shelf breaks at 120 and 140 fms. respectively, are believed to have been wave cut during the Pleistocene. Terrace bathymetry plus polished and rounded pebbles obtained in grab samples from these terraces support a wave abrasion genesis. As the seamounts were formed during the Cenozoic the continually descending lows of sea-level fluctuations through the Tertiary and Quaternary would suggest a late Pleistocene origin for both of the terraces. Upon consideration of possible hypotheses for the virtual doubling of the presently known 130-m Wisconsin

low, it would seem that there are more factors involved in sea-level changes than have been considered heretofore. The reality of a 120- to 140-fm sea-level now during the late Wisconsin should not, at this time, be rejected out of hand. (Author).

315 SCOTT, D. B., BOYD, R., and MEDIOLI, F.S. 1987. "Relative Sea-Level Changes in Atlantic Canada: Observed Level and Sedimentological Changes vs. Theoretical Models," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 87-96.

Geophysical model propose that a former path of ice retreat can be divided into sea-level zones based on the thickness of ice over the region. The predicted position of these zones fits remarkably close to the observed positions.

Fifteen different, detailed curves of relative sea-level have been obtained in the Atlantic Canadian area and three composite curves derived from these data are presented here. These data exhibit highest resolution in the last 4,000 years. but one area provides a complete record since deglaciation and two other sites provide data from 7.0 ka to the present. A clear trend is apparent in these data: relative sea-level rise is greater seaward of the former ice margin with no former shorelines above present sea-level. As one moves across the former ice margin toward the former ice center, there is evidence of early sea-level fall but no raised marine features. Closer to the ice center, old raised shorelines appear but present sea-level is rising. Close to the former ice center, relative sea-level is still falling with no evidence of any past relative sea-level rise.

Atlantic Canada demonstrates the complex inter-relationships which can develop over short distances between relative sea-level and resulting sedimentation. For interpretation of relative sea-level and sedimentation history in glacial regions, it is critical to locate the position of maximum glacial advance. Finding this position helps delineate the boundary between original areas of erosion and deposition and determines sources and quantities of sediment as sea-level modifies a coastline. It also determines whether glacial deposition will be concentrated in terrestrial, continental shelf or continental slope and rise environments. (Authors).

316 SCOTT, D. B., and GREENBERG, D. A. 1983. "Relative Sea-Level Rise and Tidal Development in the Fundy Tidal System," Canadian Journal of Earth Sciences, Vol 20, pp 1554-1564.

Previous studies of sea-level and tidal amplification in the Bay of Fundy suggested a linear increase of tidal amplitude as relative sea-level rose. New data presented here are used in a numerical tidal model in an effort to reproduce paleotidal regimes over the last 7,000 years. Five new sea-level curves covering the last 4,000 years and some previously published data extending the record back to 7,000 years before present (B.P.) are used as the data base. These data, when used together with the tidal model, indicate that tidal amplitudes increased much more rapidly between 7,000 and

4000 years ago than in the period 4,000 years ago to present. It is also shown that changes in depth within the Bay of Fundy produce little effect on the tidal amplitudes, whereas such variations in water depth on Georges Bank account for almost all the change. This calculation of tidal-amplitude changes allows calibration of sea-level curves to be made for the Bay of Fundy using higher high-water (HHW) indicators. (Authors).

317 **SCOTT, D. B., MEDIOLI, F. S., and MILLER, A. L.** 1987. "Holocene Sea-Levels, Paleoceanography, and Late Glacial Ice Configuration Near the North-Cumberland Strait, Maritime Provinces," Canada Journal of Earth Sciences, Vol 24, pp 667.

Work on new cores from old core sites in Baie Verte, New Brunswick, led to the identification of submerged salt-marsh peats, reported earlier as freshwater ones. A comprehensive sea-level curve, between 9 and 15 m below present, is based on marsh foraminiferal assemblages. These data indicate that between 4,500 and 5,400 BP relative sea-level (RSL) rise was comparatively slow (about 10 cm/100 years); the rate increased dramatically between 4,500 and 4,000 BP (1 m/100 years) and decreased between 2,000 and 4,000 BP to its present rate of 15 cm/100 years. We suggest RSL was falling before 5400 BP and that the sequence in our deepest core is similar to some observed in the Bay of Fundy and Nova Scotian Atlantic coast where early RSL fall is documented. To account for this sea-level record and others nearby we suggest that the ice history here is complex, with three separate ice caps thinning towards this area in late glacial times.

Earlier work also indicated a number of sediment sequences barren of benthonic foraminifera, suggesting a complex marine-freshwater history for the area. The study of new cores containing the same sequences indicates no barren zones but a simple transgressive sequence with a warm-water calcareous fauna followed by an agglutinated transitional estuarine foraminiferal fauna. (Authors).

318 **SCOTT, R. W., FROST, S. H., and SHAFFER, B. L.** 1988. "Early Cretaceous Sea-Level Curves, Gulf Coast and Southeastern Arabia," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 275-284.

Three surface and subsurface sections of Lower Cretaceous strata from the Gulf Coast are correlated with three comparable sections in Oman. Detailed fossil ranges and graphic correlation methods resulted in a biostratigraphic data base that could be related to the geologic time scale. Two events of relative sea-level rise are synchronous in the Gulf Coast basin and the southeastern Arabian platform and may represent eustatic sea-level rises. The intra-Aptian rise began about 115.8 Ma and in many places is represented by a sharp lithologic change, by submarine hardgrounds, or by onlap. Deep-water deposition resumed from 115.2 to 113.9 Ma. The intraCenomanian rise began approximately 94.6 Ma. In Oman, this rise is

locally represented by a submarine hardground that formed after drowning of a carbonate shelf. In the updip Gulf Coast, mid-Cenomanian paraoki and deltaic sediments were deposited upon an Albian-early Cenomanian shallow carbonate shelf. In the downdip Gulf Coast, this event either is not recognizable in deep-water muds or is represented by drowning of shallow-water carbonates. A third, intra-Albian event at 104.3 Ma may also be a eustatic sea-level rise; however, it needs to be identified in other tectonic settings. (Authors).

319 **SELIVANOV, A. O., and STEPANOV, V. P.** 1985. "Geoarcheological Investigations on the Soviet Primorye Coast: Their Application to Interpretations of Paleoclimates and Former Sea-Levels," Journal of Coastal Research, Vol 1, No. 2, pp 141-149.

Sixteen archeological sites along the coast of Soviet Primorye formed the basis for developing geoarcheological methodologies. Stages and methods of subsistence by ancient peoples are used to infer prior climatic conditions and former sea-levels. Artifact-bearing sediments, geomorphological position, and results of granulometric, mineralogical-petrographical, and spore-pollen analyses as well as radiocarbon dates were studied for the sixteen archeological sites. Three broad levels of cultural development were identified the Vestigial Neolithic, Bronze Age, and Early Iron Age. Based on three geoarcheological investigations, it was determined that sea-level rose repeatedly to higher stands (compared to the present) during the Holocene. Transgressions are thought to have occurred 3,000 year ago and again at about 2,000 BP. These high stands are tentatively identified with the Atlantic period and also correspond with recognized relict shorelines along the Japanese coast. The correlation between changes in sea-level and monsoon climate in coastal Primorye is attributed to the Peterson-Shnitnikov mechanism where a high monsoon index corresponds to a lowering of sea-level and a low index to a rising sea-level. A possible exception occurred 2,000 years ago when a transgression coincided with a high monsoon index. It was probably a response to Holocene warming at this time. (Authors).

320 **SEMENIUK, V.** 1985. "The Age Structure of a Holocene Barrier Dune System and Its Implication For Sea-Level History Reconstructions in Southwestern Australia," Marine Geology, Vol 67, pp 197-212.

The Leschenault Peninsula in southwestern Australia is a Holocene retrograded barrier dune system. The barrier separates an estuarine-lagoon from the Indian Ocean and, in Holocene time, the barrier has migrated over estuarine sediments deposited leeward of the dune system. Stratigraphic studies and radiocarbon dates indicate that the barrier has had a complex history resulting in composite internal structure. The barrier is composed of three members, each of which was emplaced during a discrete historical phase in the Holocene when relative sealevel stood: (1) at 2 or 3 m below present level between ca. 8,000-5,500 ^{14}C years B.P.; (2) 3 or 4 m above present level about ca. 4,800-3,000 ^{14}C years B.P.; and (3) at present level ca. 2,800 ^{14}C years B.P.-present. The fact that the barrier still exists as a structure even though it has experienced such widely fluctuating sealevels indicates that

rising and falling sealevels may not totally destroy barrier systems. The sealevel history at Leschenault Peninsula also is at variance with studies of accretionary sequences elsewhere along the southwestern Australian coast and suggests very localized tectonic influences, a factor not fully explored in Holocene sequences of the Perth Basin. (Author).

321 **SEMENIUK, V., and SEARLE, D. J.** 1986. "Variability of Holocene Sea-Level History Along the Southwestern Coast of Australia - Evidence for the Effect of Significant Local Tectonism," Marine Geology, Vol 72, pp 47-58.

Holocene sea-level records for the interval 7,400 ^{14}C years B.P. to the present were determined from accretionary sequences at three separate localities within the Perth Basin of southwestern Australia. The three records all differ dramatically despite an overall separation of sites of only 170 km. At the northernmost site the record shows sealevel was ca. 1.0 m below present MSL 7,415 ^{14}C years B.P. and that it gradually rose to reach its present position ca. 5,100 ^{14}C years B.P. with no evidence for a raised sealevel nor for significant oscillations. the record at the middle site shows a steadily declining sealevel from an initial high of ca. 2.5 m at 6,400 ^{14}C years B.P., and is consistent with eustatic-hydroisostatic interpretations. The southernmost site shows the most complex sealevel history of the three with a still-stand at 2 or 3 m below present between 7,000 and 5,500 ^{14}C years B.P., an abrupt rise to 3 or 4 m above present MSL between 4,800 and 3,800 ^{14}C years B.P., followed by a decline with sealevel reaching its present position ca. 2800 ^{14}C years B.P.

Considered jointly the three differing sealevel records imply significant local tectonism during the Holocene along the southwestern coast of Australia. The data further indicate that this coast can no longer be considered as tectonically stable as previously assumed and consequently the sea-level evidence can no longer be considered to reflect only eustatic and eustatic-hydroisostatic influences. (Authors).

322 **SEYMOUR, R. J., STRANGE, R. R., CAYAN, D. R., and NATHAN, R. A.** 1985. "Influence of El Niños on California's Wave Climate," Proceedings of the 19th Coastal Engineering Conference, pp 557-592.

Waves with exceptional height and periods caused severe damage along the coast of California in 1982-83. Because these large wave events coincided with a strong El Niño-Southern Oscillation (ENSO) climatic anomaly, which occurs 20-25 times per century, there was interest in determining if the extreme waves resulted from the ENSO or its related features. the meteorological setting featured a very large and intense low pressure zone over the north-central Pacific. Associated with this Pacific-wide pattern, a series of large mid-latitude storms developed at about weekly intervals and produced exceptionally long fetches directed at the California Coast.

Two time series of extreme wave events, using buoy data after 1981 and hindcasts before, were used covering the period from 1900 to 1984. One series considered waves with significant heights greater than 3 m (10 ft) and the second for those greater than 6 m (20 ft). These were compared with a time

history of ENSOs for the same period. A strong association was established between northern hemisphere winters during ENSO years and large wave events in Southern California. Strong ENSO winters had the largest storm waves, moderate ENSOs less intense waves, and weak ENSOs tended not to have storm waves greater than the threshold vale used in this study. The correlation between large waves and ENSO years is significant at the 1% level. The correlation between lack of large waves and non-ENSO years is significant at the 0.5% level.

Because of the great southerly extent of the most energetic storms, a large number of energetic wave trains approach the coast from the west, rather than the northwest, as previously assumed by many. ENSO winters are responsible for producing all of the wave events in this study with both heights greater than 6 m and periods of peak energy longer than 19 seconds.

Five out of nine eastern Pacific tropical storms making landfalls on California in the 85 year period occurred during the late northern summer of ENSO years. (Authors).

323 **SHENNAN, I. 1983.** "Analysis and Interpretation of Holocene Sea-Level Data," Nature, London, Vol 302, No. 5907, pp 404-406.

The geography of the geoid and the lack of an acceptable methodology and definition of terms for sea-level studies have impeded the realization of the objectives of the International Geological Correlation Program Project 61 on Holocene sea-level changes. These were to establish a graph of the trend of mean sea-level over the globe and the relationship of sea-level, climate change, and the global ice budget. A solution to the problems of correlation is proposed. The use of terms transgression and regression has been a major cause of misinterpretation, and the terms transgressive overlap and regressive overlap have been proposed as descriptive lithostratigraphic terms, in which no process is implied. The processes involved in the development of coastal stratigraphic sequences are dependent upon the position and rate of change of sea-level, and these sequences contain evidence of tendencies of sea-level. The application of the concept of sea-level tendency permits meaningful correlations between rising and subsiding areas and introduces an objectivity to correlation schemes showing transgression sequences. (Author).

324 **SHEPARD, F. P. 1960.** "Rise of Sea-Level Along Northwest Gulf of Mexico," in Shepard, Francis P., Editor, Recent Sediments, Northwest Gulf of Mexico," American Association of Petroleum Geologists Bulletin, p 394.

Samples and borings on the continental shelf and in the bays along the Texas coast have provided relict nearshore and shallow-bay macro-organisms, allowing the dating of the Holocene (post-glacial) rise of sea-level among this relatively stable coast. The rise of sea-level has been dated from 300 ft below the present at 17,000 years before the present, to about 40 ft at 8,000 years B.P. There is evidence suggesting that the rise has continued very slowly during most of the remaining period, but there is a possibility that the data are deceptive and that either the levies have fluctuated or the sea has been fairly constant for several thousand years.

Fluctuations during the 17,000-8,000 B.P. interval are indicated by eastward sloping drowned barriers that can be best explained as due to brief periods of regression produced by renewed growth of glaciers on the lands. These periods appear to correspond with some of the known readvances of the continental ice sheets.

The history of rise along the Texas coast appears to agree with that along other stable areas. On the other hand, the records obtained from the area around the Mississippi Delta appear to indicate an independent subsidence of that area of the order of about 1 ft per century. (Author).

325 **SMITH, R. A., and LEFFLER, R. J.** 1980. "Water Level Variations Along California Coast," Journal of the Waterway Port, Coastal and Ocean Division, Vol 106, No. WW3, pp 335-348.

Long-term sea-level variations relative to land at widely separated locations along the California coast show differences in rates and directions of change. A graphic compilation of 123 year of annual sea-level variations at the Golden Gate are presented for the first time. The sea-level elevations over the period of record at Golden Gate show intervals of rise, fall, and little movement relative to land. By referencing the highest water level each year to the tidal datum of MHHW, the maximum expected height of time can be computed without the necessity of applying corrections for long-term changes and range variations. The maximum height expected for a 100-year period, as computed from the observed data at the Golden Gate, is 71 cm above MHHW. San Diego, Los Angeles, San Francisco, and Crescent City all exhibit a maximum frequency of highest water levels each year in December. The same four locations also exhibit a maximum water level height in December, January, or February. (Conclusions, Authors).

326 **SMITH, D. A., SCOTT, D. B., and MEDIDI, F. S.** 1984. "Marsh Foraminifera in the Bay of Fundy: Modern Distribution and Application to Sea-Level Determinations," Maritime Sediments and Atlantic Geology, Vol 20, pp 127-142.

Although marsh foraminiferal zonations are comparatively well known for most of Atlantic Canada, data from the vertically expanded marsh zones in the Bay of Funday are insufficient for marsh foraminiferal zonations that can be used to accurately determine former sea-levels. In this paper we present data from two well-documented surface transects that illustrate vertical ranges of marsh foraminifera in the Bay of Fundy. Trochammina inflata characterizes the highest margin with a zone la of 20 cm vertical range. Tiphotrocha comprimata together with T. inflata comprise zone lb (vertical range 75 cm) while Mdiammina fusca and other low marsh species characterize zone II faunas (vertical range 450 cm). As in Atlantic marshes the fauna nearest the higher high water level produces the best accuracy for relocating former sea-levels while low marsh (zone II) is not a good indicator. (Authors).

327 SNEH, Y., and KLEIN, M. 1984. "Holocene Sea-Level Changes at the Coast of Dor, Southeast Mediterranean," Science, Vol 226, pp 831-832.

Geological, geomorphological, and archeological data of changes in sea-level during the Holocene at the Mediterranean coast of Dor provide a eustatic curve of the region. This curve shows that sea-level was approximately 2 ms below the present level 4,000 years ago, rose to 1 m below the present level 3,000 years ago, and was 1 m higher than the present level 1,500 years ago. It then dropped to 1 m below the present level about 800 years ago. (Authors).

328 SPANIER, E. 1987. "A Fossil Record of Shell Boring: Possible Evidence for Sea-Level Changes in the Red Sea, Estuarine, Coastal and Shelf," Science, Vol 24, pp 873-879.

An aggregation of fossil shells of the Indo-Pacific muricid snails Chicoreus ramosus was found in the northern part of the island of Tiran, Red Sea. The site was 7 m above the present mean sea-level. Radiocarbon dating of these shells indicated an age of 1,570 $\pm$ 80 years BP. Some of these shells bore-drilled holes, most of them uncompleted. Biological study revealed that such holes were probably drilled by conspecifics in the absence of alternative food after they had been disconnected from the sea. Since there is no evidence of human activity in this part of Tiran, the author suggests that such conditions could be caused only by a physical process that changed the relative water level. In accordance with the character of the drilled holes and the short period which muricids maintain reproductive aggregates, the author also postulates that such a physical process must have been a relatively rapid one. (Author).

329 SPILLANE, M. C., ENFIELD, D. B. and ALLEN, J. S. 1987. "Intraseasonal Oscillations in Sea-Level Along the West Coast of the Americas," Journal of Physical Oceanography, pp 313-325.

Hourly observations of coastal sea-level at stations from Peru to British Columbia are analyzed for low-frequency content. A space-time contour plot of sea-level, from four years of data during the 1971-75 period, shows the meridional structure of the seasonal cycle and interannual variability associated with the 1972-73 El Niño. Oscillations with intraseasonal periods of 36-73 days are also evident, coherent over alongshore distances of several thousand kilometers. Further investigation using spectral methods and empirical orthogonal function analysis in the frequency domain reveals, in particular, that intraseasonal sea-level variability has a peak in spectral density along the coasts of South America, Central America and Mexico, with high coherence from near the equator (Tumaco, 2 N) north to central California (34 N) and south to at least Callao (12 S). Phase propagation north of the equator is poleward at 150-200 kilometers/day. Atmospheric pressure, alongshore wind stress and wind stress curl, derived from Fleet Numerical Oceanography Center data for the Northern Hemisphere, are used to assess the importance of local atmospheric forcing. The low coherence between

sea-level and these fields in the intraseasonal frequency band suggests that the observed oscillation may be a coastally propagating response to remote processes in the equatorial Pacific waveguide. (Authors).

330 SPOERI, R. K., ZAHAWA, C. F., and COULOMBE, B. 1985. "Statistical Modeling of Historic Shore Erosion Rates on the Chesapeake Bay in Maryland," Environmental Geology Water Sciences, Vol 7, No. 3, pp 171-187.

Few strong relationships exist along the Chesapeake Bay shoreline between the historic erosion rate and the distribution of any of several coastal parameters which were defined and tested using traditional regression and discriminant analysis procedures. To develop a simple predictive equation for shore erosion that could be used by coastal managers, the entire Chesapeake Bay shoreline was partitioned into naturally occurring reaches 2-5 km in length, and the historic erosion rate on each reach was modelled as a function of five variables: (a) shoreline type, (b) "100-year" storm surge height, (c) mean tide range, (d) wave climate, and (e) potential littoral drift rate. The statistical analysis yielded a multiple correlation coefficient (r^2) of 30.8%, discriminant analysis showed only the first two variables listed above are useful predictors (i.e., statistically significant) of historic erosion rates. A 95-mile portion of the same bay shoreline in Queen Anne's and Talbot counties was then partitioned into shorter reach lengths (1/2-2 km) and more variables were included. The multiple correlation coefficient (r^2) improved slightly to 32.9%, but only shoreline type and potential littoral drift rate were found to be useful predictors of historic erosion rates. Curiously, the ability to model statistically the historic shore erosion rate is best on those reaches already substantially protected by structures. For Queen Anne's and Talbot counties, the multiple regression coefficient improved to 61.5% when only reaches 1/2-2 km in length protected by structures were considered. (Authors).

331 STANLEY, D. J. 1988. "Subsidence in the Northeastern Nile Delta: Rapid Rates, Possible Causes, and Consequences," Science, Vol 240, pp 497-500.

Holocene fluvial and marine deposits have accumulated in a graben-like structure on the northeastern margin of the Nile delta. This part of the delta, which includes Lake Manzala, Port Said, and the northern Suez Canal, has subsided rapidly at rates of up to 0.5 cm/year since about 7500 years ago. This subsidence has diverted at least four major distributaries of the Nile River into this region. The combined effects of continued subsidence and sea-level rise may flood a large part of the northern delta plain by as much as 1 m by the year 2100. The impact of continued subsidence, now occurring when sediment input along the coast has been sharply reduced because of the Aswan High Dam, is likely to be substantial, particularly in the Port Said area and as far inland as south of Lake Manzala. (Author).

332 STAPOR, F.W., Jr., and MATHEWS, T. D. 1983. "Higher-Than-Present Holocene Sea-Level Events Recorded in Wave-cut Terraces and Scarps: Old Island, Beaufort County, South Carolina," Marine Geology, Vol 52, pp M53-M60.

Wave-cut terraces and scraps record at least two higher-than present Holocene sea-level events in coastal South Carolina. The higher event reached 110 cm and the lower 80 cm above local, mean spring high water (MSHW). These events occurred subsequent to the formation of the Holocene Old Island barrier island and prior to Wilmington aboriginal occupation 1600 years ago. Shell middens are located on the terrace surfaces. These wave-cut features were formed in a marsh-filled lagoon sheltered from the open ocean by seaward barrier islands. These terraces and scarps are evidence supporting the higher-than-present sea-level events predicted for this region by the Clark et. al. (1978) geophysical model of Holocene sea-level recovery. In addition, they support a Fairbridge (1961) type Holocene sea-level curve, one characterized by oscillations above and below present position. Holocene sea-level fluctuations probably were a prime factor in the episodic progradation of this area, given that in this vicinity the nearshore region is the primary sand source. (Authors).

333 STERNS, H. T. 1974. "Submerged Shorelines and Shelves in the Hawaiian Islands and a Revision of Some of the Eustatic Emerged Shorelines," Geological Society America, Bulletin 85, pp 795-804.

The paper presents new C^{14} and uranium series dates on Oahu and their bearing on the dating of fluctuations of sea-level due to glacioeustatism during the Wisconsinan. The -60- and -120-ft shorelines are shown to be Wisconsinan. Scuba and submersible diving has made it possible to study the submerged shorelines. Some of the submerged shorelines are notches in vertical cliffs and were not previously found by detailed soundings. The -350-ft shelf, previously thought to be a drowned wave-cut platform, proved to be a drowned coral reef. Shorelines and drowned reefs indicate stillstands below sea-level at 15, 30, 60, 80, 120, 150, 185, 205, 240±, 350, 1,200 to 1,800, and 3,000 to 3,600 ft. Those above -450 ft are thought to be glacioeustatic. Those below -450 ft are the result of subsidence. (Author).

334 STRUB, P. T., POWELL, T., and GOLDMAN, C. R. 1985. "Climatic Forcing: Effects of El Niño on a Small, Temperate Lake," Science, Vol 227, pp 55-57.

Temperature profiles measured regularly for 21 years reveal the interannual differences in winter-to-summer heat gain in Castle Lake, California, a small subalpine lake. Year-to-year changes in large-scale climatic surface forcing, especially the amount of snowfall from February through April (which determines the date of thaw) coupled with the early heating and wind mixing after thaw, causes this interannual variation. The seasonal thermal structure for years in which the lake gains significantly more or less heat than normal--all of the El Niño years and several others--shows that the depth of the mixed layer and the mixing of heat into the stratified thermocline region

control the storage of heat. The temperature of the mixed layer does not reflect abnormal thermal storage. Variations in mixing during early spring, which controls the heat contents at Castle Lake, may also affect the annual average of the primary productivity. (Authors).

335 STURGES, W. 1967. "Slope of Sea-Level Along the Pacific Coast of the United States," Journal of Geophysical Research, Vol 72, No. 14, pp 3627-3637.

The long-term mean slope of sea-level along the Pacific coast of the United States is estimated for comparison with the rise from south to north reported by precise leveling. Oceanographic evidence does not support the leveling results. Steric levels at the coast relative to 1000 db strongly suggest that the slope reported by leveling is nonexistent. Careful examination of the 1,000-db surface shows it to be a sufficiently level reference surface along the coast. Mean sea-level at Neah Bay, Washington, is found to stand 9 cm lower than at San Diego, California, rather than 46 cm higher as suggested by leveling. A leveling error that could cause a slope of the observed sign and amount is discussed. The 9-cm difference found in the present study is consistent with the effect of changing latitude as the California Current flows south. (Author).

336 STUVIER, M., and DADDARIO, J. J. 1963. "Submergence of the New Jersey Coast," Science, Vol 142, pp 951.

A series of five radiocarbon dates obtained from samples taken along the base of the lagoon between the Brigantine City Barrier and the mainland indicates a rate of submergence of 3 m per millennium between 6,000 and 2,600 years before present. During the last 2600 years the average submergence has slowed down to only 1.2 to 1.4 m per millennium; the general picture of a rapid rise and the subsequent slackening is in agreement with results published for the New England area. (Authors).

337 SUTER, J. R. 1986. "Buried Late Quaternary Fluvial Channels on the Louisiana Continental Shelf," Journal of Coastal Research, Vol SI, No. 1, pp 27-37.

Analysis of over 20,000 km on high-resolution seismic profiles, supplemented by vibracores and platform borings, on the southwest Louisiana continental shelf has revealed extensive systems of buried channels in late Quaternary sediments. A fluvial origin of the channel systems is indicated by their continuity from the nearshore to the shelf break, as well as the areal pattern, and cross sectional dimensions of as much as 5 km in width and 50 m in depth. Some channels are comparable in size to, or are even larger than, those of the modern Mississippi River, and may represent former positions of this system.

Established fluvial systems extend themselves across exposed continental shelves during periods of lowered sea-level. These channels, buried during

subsequent sea-level rise, aid in the identification of erosional unconformities and thus in determining sea-level history. Channel systems on the southwest Louisiana continental shelf have been recognized at five different levels, representing regressive periods that are interpreted to range from pre-Wisconsinan to Holocene in age.

Sediments contained within the channels and associated estuarine deposits make up a substantial part of the shelf stratigraphy. The extent and size of these features illustrate the significance of fluvial channels and associated facies in the stratigraphy of continental shelves influenced by fluctuating sea-levels. (Author).

338 **SUTER, J. R., BERRYHILL, H. L. JR., and PENLAND, S.** 1987. "Late Quaternary Sea-Level Fluctuations and Depositional Sequences Southwest Louisiana Continental Shelf," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 199-221.

Interpretations of over 20,000 line km of single-channel, high-resolution seismic-reflection profiles, coupled with nearshore vibracores and logs of industrial platform borings, provide the data base for determining the history and stratigraphy of late Quaternary sea-level fluctuations on the southwest Louisiana continental shelf. Regional uncomformities, formed by subaerial exposure of the shelf during glacio-eustatic sea-level falls and modified by shoreface erosion during ensuing transgression, serve as markers to identify the boundaries of depositional sequences. Unconformities are recognizable on seismic profiles by high-amplitude reflectors as well as discordant relationships between reflectors.

Within the upper Quaternary section, six depositional sequences have been recognized. Five of these are related to glacio-eustatic fluctuations, involving sea-level fall close to, or beyond, the margin of the continental shelf. Three of these fluctuations culminated in the deposition of shelf-margin delta sequences. Extensive fluvial channeling characterizes the regressive phase of these sequences. Transgressive phases are marked by infilling of fluvial channels, floodplain aggradation, truncation, or deposition of sand sheets, depending upon sediment supply and rate of sea-level rise. Sequences 4 and 5 are correlated with the late Wisconsinan glacial stage and Holocene transgression. The upper portion of sequence 5 consists of an early Holocene Mississippi delta complex. Abandonment and transgression of this delta are responsible for the formation to those driven by glacially-controlled sea-level changes. (Authors).

339 **TABOTA. S., THOMAS, B., and RAMSDEN, D.** 1986. "Annual and Interannual Variability of Steric Sea-Level Along Line P in the Northeast Pacific Ocean," Journal of Physical Oceanography, Vol 16, pp 1378-1398.

Twenty-five and 22 years of hydrographic-STD casts from Station P and Line P, respectively, have been utilized to describe the annual and interannual variability of thermosteric, halosteric and total steric heights. In

the offshore region beyond the continental slope thermosteric effect dominates the annual cycle of total steric height, whereas near the coast over the continental shelf halosteric effect controls the height. In between, over the slope, both temperature and salinity effects contribute almost equally to the annual cycle of height. Offshore, the annual change of steric height relative to 1000 db resembles that relative to 100 db, but as the coast is approached, the change due to the deeper water becomes more important. The heat budget within the upper 100 db of water determines most of the annual range of steric height offshore, but near the coast both dilution due to precipitation and runoff in winter and concentration due to upwelling of cool, saline water in summer govern the annual cycle of height. The annual variation of coastal, baroclinic currents appears to account for the observed annual range of adjusted mean sea-level along the coast. Local currents seem to be the main factor affecting coastal sea-level and not the general, large-scale oceanic circulation offshore. Considerable interannual variability of steric height is present everywhere along the Line, but it is difficult to determine any well-defined periodicity in the time-series data. "Spectral" maxima at approximately 6, 4, 3 and 2 years in addition to the strong annual period are present at various locations along the Line but only the six-year cycle at Station P can be considered reliable. Due to the limited amount of data along the Line, it is difficult to assign significance to these results. In the open ocean the interannual variability appears to be related to the time-integrated divergence of the Ekman transport. (Authors).

340 **THOM, B. G., and CHAPPELL, J.** 1975. "Holocene Sea-Levels Relative to Australia," Search, Vol 6, No. 3, pp 90-93.

In this report the authors present new results and evaluate recently published data to demonstrate that Holocene sea-level change relative to Australia differed substantially from the North Atlantic pattern. The differences are discussed in the light of new interpretations of global isostasy. (Introduction).

341 **THOM, B. G., and CHAPPELL, J.** 1978. "Holocene Sea-Level Change: An Interpretation," Philosophical Transactions, Royal Society of London, A. Mathematical and Physical Sciences, Vol 291, pp 187-194.

Interpretation of factors responsible for land-sea-level change in areas such as the Great Barrier Reef involve an appreciation of not only the field evidence purporting to show change, but also the theoretical models which attempt to explain depth variations in shorelines of a given age. Relative movements in sea-level in Holocene time may result from a number of factors operating either external to the study area (e.g. glacio-eustatic, and broad-scale hydro-isostatic deformation of the globe resulting from the last deglaciation and sea-level rise), or those whose effects are essentially local (e.g. changes in circulation and tidal levels within partially enclosed water bodies induced by sedimentation or biogenic reef growth, meterological changes affecting the magnitude and frequency of storminess, regional flexures and/or faulting, and hydro-isostatic deformation of shelves and adjacent coasts

accompanying the Postglacial Transgression). In this paper, data from the northern Great Barrier Reef Province are evaluated in relation to various causes of sea-level change. Emphasis is placed on explaining variations in relative sea-level position by hydro-isostatic theory. Deflexion in the ocean margin 'hinge zone' varies with continental shelf geometry and rigidity of the underlying lithosphere. The fact that the oceanic crust meets the continental crust quite abruptly east of the study areas, dictates that moderately strong flexures occur, and that variations in Holocene hydro-isostatic flexure in the Great Barrier Reef Province are partly explainable in these terms. (Authors).

342 THOM, B. G., and ROY, P. S. 1985. "Relative Southeast Australia in the Holocene," Journal of Sedimentary Petrology, Vol 55, No. 2, pp 257-264.

An examination of tide gage records from Newcastle and Syndey showed distinctive, steplike fluctuations in the order of 10 cm, superimposed on a nearly static sea-level trend. Based on annual mean values of sea-level for Syndey and Newcastle, local sea-level trends are more of a response to long-term variations in regional storm patterns and associated climatic events than to global trends in sea level. The authors concluded from available records that the degree of sea-level rise in southeast Australia is smaller than the rates observed in many other parts of the world. (Gorman)

343 THOMAS, R. H., THOMPSON, D. E., BINDSCHADLER, R. A., and MacAYEAL, D. R. 1983. "Ice-Sheet Melting and Sea-Level," Proceedings of Coastal Zone '83, Third Symposium on Coastal and Ocean Management, Vol III, pp 2846-2857.

The major potential for sea-level rise during periods of climatic warming is by melting of polar ice. At present, there is considerable summer melting from parts of the Greenland ice sheet, and this would increase under warmer conditions. However, there is little surface melting in Antarctica, and anticipated climatic warming would cause melting only in low-lying area. Nevertheless, this may weaken the large, floating ice shelves into which flows most of the ice draining from Antarctica. A probable result would be significantly increased ice-drainage rates and more Antarctic icebergs. Portions of the ice sheet that rest on continental shelf could become unstable and collapse. If this happens, sea-level increase would be slow at first but would accelerate rapidly once the collapse became irreversible.

Although definitive predictions of ice sheet response to prescribed climatic warming cannot yet be made, we are trying to estimate probable bounds to the response of major ice drainage basins. We use a very simple model to describe the glacier response to changes in the ice shelves wrought by a warming climate. Climate parameters are from the GISS simulations, and related ocean characteristics are from a study by A. Gordon. (Authors).

344 TITUS, J. G. (Editor) 1986. Effects of Changes in Stratospheric Ozone and Global Climate. Volumes 1-4. United States Environmental Protection Agency, United Nations Environment Program.

This report examines the possible consequences of projected changes in stratospheric ozone and global climate resulting from emissions of chlorofluorocarbons, carbon dioxide, methane, and other gases released by human activities.

The four volumes of this report comprise the proceedings of a conference, "International Conference on the Health and Environmental Effects of Ozone Modification and Climate Change", sponsored by U.S. Environmental Protection Agency and by the United Nations Environment Program.

Several noteworthy articles include:

(a) Robert H. Thomas, "Future Sea-level Rise and Its Early Detection by Satellite Remote Sensing", presents new calculations of the possible contribution of Antarctica, and combines then with previous estimates for the other sources, projecting that a worldwide rise in sea-level of 90 to 170 centimeters by the years 2100 with 110 centimeters most likely.

(b) Per Bruun, "Worldwide Impact of Sea-level Rise on Shorelines", argues that with a combination of coastal engineering and sound planning society can meet the challenge of a rising sea. He discusses a number of engineering options, including dikes (levees) and seawalls, and adding sand to recreational beaches that are eroding with a section on the battle that the Dutch have fought with the sea for over one thousand years.

(c) Eric C.F. Bird, "Potential Effects of Sea-level Rise on the Coasts of Australia, Africa, and Asia," examines the implications of sea-level rise for other African and Asian nations, as well as Australia.

(d) Stephen P. Leatherman, "Coastal Geomorphic Impacts of Sea-level Rise on Coasts of South America", examines the implications of sea-level rise for South America.

(e) Richard A. Park, et al., "Predicting the Effects of Sea-level Rise on Coastal Wetlands, "focus on the expected drowning of coastal wetlands in the United States. Using a computer model of over 50 sites, they project that 40-75 percent of existing U.S coastal wetlands could by lost by 2100. (Modified Introduction).

345 **TITUS, J. G., HENDERSON, T. R., and TEAL, J. M.** 1984. "Sea-Level Rise and Wetlands Loss in the United States," National Wetlands Newsletter, Vol 6, No. 5, pp 3-6.

For the last several thousand years, sea-level has risen so slowly that, for most practical purposes, it has been constant. This slow rate of rise has enabled coastal wetlands to be far more extensive than was possible when sea-level was rising rapidly. However, recent developments suggest that rising sea-level may increasingly threaten coastal wetlands in the future. Evidence of wetland loss from current sea-level trends is confined to a few areas. Wetlands in Louisiana are converting to open water at a rate of 40 square miles per year largely because relative sea-level is rising one inch every three years. (Tidal gages measure relative sea-level rise, which equals land subsidence plus world-wide sea-level rise.) Along the Eastern Shore of

Maryland, a rise of one inch per decade has been cited as a cause of wetlands loss.

These isolated observations may become the general rule in the future. Although world-wide sea-level rose only four to six inches in the past century, the National Academy of Sciences and the Environmental Protection Agency have estimated that the expected "greenhouse" warming is likely to cause a one to five ft rise in the next century. (Introduction).

346 **TITUS, J. G., LEATHERMAN, S. P., EVERTS, C. H., KRIEBEL, D. L., and DEAN, R. G.** 1985. "Potential Impacts of Sea-Level Rise on the Beach at Ocean City, Maryland," United States Environmental Protection Agency, Washington, DC, pp 176.

This study examines the potential implications of sea-level rise for efforts to control erosion of the beach at Ocean City, Maryland, a typical Atlantic Coast resort. Because current trends in sea-level and other factors are already causing significant erosion at Ocean City and other ocean beach resorts, strategies for addressing coastal erosion constitute a class of near-term decisions that may depend on sea-level rise. Because land and improvements are often worth well over one million dollars per acre in these areas, and erosion increases the likelihood of storm damage and federal disaster payments, the success of erosion control measures has great economic importance to the nation. The authors hope that this report will promote a reasoned consideration of the long-term consequences of sea-level rise, and thereby enhance the eventual success of erosion control strategies at Ocean City and other coastal communities.

In this report, three independent teams of coastal process scientists estimate the erosion that will take place at Ocean City for three scenarios of future sea-level rise: (1) current trends of 1 ft per century along the Atlantic coast; (2) the National Academy of Sciences estimate of a 2-1/3 ft global rise in the next century with an 11 inch rise by 2025; and (3) the EPA mid-high scenario of a global rise of 4-1/2 ft in the next century and 15 inches by 2025. The quantity of sand necessary to maintain the current shoreline is also estimated for each of the scenarios. Using these estimates and previous studies by the Corps of Engineers and others, the potential costs of erosion control are also examined. (Summary).

347 **TRENBERTH, K. E., and PAOLINO, D.A., Jr.** 1980. "The Northern Hemisphere Sea-Level Pressure Data Set: Trends, Errors and Discontinuities," Monthly Weather Review, Vol 108, pp 855-872.

A detailed examination of the Northern Hemisphere monthly mean sea-level grid-point pressures shows a disappointingly large number of problems. The data set extends from 1899-1977 but has originated from eight different sources and discontinuities have been identified with every change in source. We have documented corrections for many of these and have also catalogued 3263 serious errors. These have been corrected or set to missing. Most of the errors are over Asia and are predominant before 1922 or during World War II.

Analyses of several different aspects of the data that reveal both the problems and real changes in the atmospheric circulation are presented, along with a comparison of the monthly mean operational U.S. Navy versus U.S.

National Meterological Center analyses. A plea is made for a greater effort in archiving quality controlled climatological data. (Authors).

348 TRENBERTH, K. E. 1981. "Seasonal Variations in Global Sea-Level Pressure and the Total Mass of the Atmosphere," Journal of Geophysical Research, Vol 86, No. C6, pp 5238-5246.

The annual cycles of sea-level and surface pressures and the atmospheric pressure owing to water vapor have been analyzed in detail. Global sea-level pressures undergo an annual cycle of 0.5 mbar range with a maximum in the northern winter. Global surface pressures, which represent the total mass of the atmosphere, also undergo an annual cycle of 0.5 mbar range but with the maximum in the southern winter. The changes in water concentrations are responsible for the latter-water vapor has a maximum in the southern winter. The constancy of the mass of dry air is used as a check on the accuracy of computations. The total mass of the atmosphere is 513.7×10^{16} kg with a standard error of 0.02×10^{16} kg and an annual cycle of amplitude 0.1×10^{16} kg. The corresponding global mean surface pressure of the atmosphere is 984.68 mbar. The mean total mass of water vapor is 1.3×10^{16} kg which corresponds to 2.53 cm of precipitable water or 12906 km^3 of water at 0° C. The distribution of pressure and mass as a function of latitude are also presented. (Modified Abstract).

349 ULZEGA, A., LEONE, F., and ORRU, P. 1986. "Geomorphology of Submerged Late Quaternary Shorelines on the Southern Sardinian Continental Shelf," Journal of Coastal Research, Vol SI, No. 1, pp 73-82.

Various evidence of submerged sea-levels at different depths has been found on the Sardinian continental shelf. In the Gulf of Cagliari in southern Sardinia, the following submerged morphologies are present: marine abrasion platform on the Miocene calcareous bedrock, conglomerates and beach sandstones cemented in an inertial environment, and backshore depressions infilled with fine sediments. The beach rocks at -40 to -60 m are attributed to the Holocene transgression on the basis of a detailed geomorphological study. At

the same depth the mottling of the abrasion platform by karstic dissolution, probably occurred during the last glacial regression. A comparison with submerged sea-levels of the same range studied in other parts of the Sardinian continental shelf confirms that the stillstand time during the Holocene

transgression was particularly long. During this stillstand climatic conditions have favored the formation of beach rock. (Authors).

350 **UPCHUPI, E., and AUBREY, D. G.** 1988. "Suspect Terranes in the North American Margins and Relative Sea-Levels," Journal of Geology, Vol 96, pp 79-90.

Sea-level trends deduced from tide gages show considerable variation along strike both on the convergent (western) and divergent (eastern) edges of the North American plate. That portion of the variation unrelated to Quaternary glaciation and deglaciation may reflect the differential reaction to extension and sediment loading in the east, and in the west subduction and translation of terranes welded onto the North American craton. These autonomous blocks appear to impart distinct signatures on records of relative sea-levels, suggesting promise in deducing complex terrane topography of other margins using tide-guage data. Uncertainties in these deduction can be reduced only with expanded tide gage coverage or by application of new geodetic techniques (Very Long Baseline Interferometry or differential Global Positioning System).

351 **UUSITALO, S.** 1960. "The Numerical Calculation of Wind Effect on Sea-Level Elevations," Tellus, Vol XII, No. 4, pp 427-435.

An iteration method has been developed which uses finite differences for calculating water level elevation and water transport. To this end, the equations of motion were integrated over the depth and transformed into an implicit difference equation system. The equations were solved by the aid of an electronic computer. Two main cases were calculated, and in one instance the water levels were checked with the real ones. (Author).

352 **VAIL, P. R.** 1980. "Global Cycles of Sea-Level Change and Their Role in Exploration," Proceedings of the World Petroleum Congress V.2: Exploration Supply and Demand, Bucharest, Rom., Sep. 9-14, 1979, Heyde, and Son, Philadelphia, PA, pp 95-104.

This study discusses global cycles of sea-level change, a summary of procedures for seismic stratigraphic analysis using global cycles, and four major applications of sea-level cycles in petroleum exploration. (Compendix citation).

353 VEEH, H. H. 1966. "Th^{230}/U^{238} and U^{234}/U^{238} Ages of Pleistocene High Sea-Level Stand," Journal of Geophysical Research, Vol 71, pp 3379-3386.

Unrecrystallized fossil corals occurring in their growth positions between 2 and 9 ms above sea-level at many locations in the Pacific and Indian oceans have been dated by the Th^{230}/U^{238} methods. Where possible, recent corals were also collected and analyzed for their uranium and thorium isotopes. The uranium contents of the corals were determined fluorimetrically; the U^{234}/U^{238} ratios and the thorium concentrations were ascertained by alpha spectrometry. The Th^{230}/U^{238} ages of the fossil corals range from 90,000 $\pm$ 20,000 to 100,000 $\pm$ 40,000 years and the $U^{234}/^{238}$ ages from 80,000 $\pm$ 50,000 to 180,000 $\pm$ 60,000 years. Absence of Th^{230} in the recent corals and absence of Th^{290} in both the recent and the fossil corals confirm the assumption that the Th^{230} found in the fossil corals resulted solely from radio active decay of its parent uranium. Control samples of pre-Pleistocene material showed radioactive equilibrium between the various members in the U^{238} decay chain. Both the internal consistency of the ages, within experimental error, and the agreement between the Th^{230}/U^{238} and U^{234}/U^{238} ages, strongly support the general validity of these ages. The similarity of the Th^{230}/U^{238} ages of Pleistocene coral reefs to those of like elevations above sea-level in many localities suggests a eustatic sea-level stand higher than now at about 120,000 $\pm$ 20,000 years ago, possibly during an interglacial stage of the Pleistocene. (Author).

354 VAN DER VEEN, C. J. 1987. "Projecting Future Sea-Level," 1987, Surveys in Geophysics, Vol 9, No. 3-4, pp 389-418.

As a starting point for the sea-level rise scenario discussed here it is assumed that the globally-averaged increase of surface air temperatures will amount to 2 to 4°C in the second half of the next century (ie around 2085 AD). The projection for future sea-level presented here suggest that by 2085 AD, global sea-level stand will be 28-66 cm higher than the present level, which implies a rate of sea-level rise of about 2 to 4 times that observed during the last 100 year. Our scenario does not include a contribution resulting from the possible collapse of the West Antarctic Ice Sheet. (Author)

355 WALCOTT, R. I. 1972. "Past Sea-Levels, Eustasy and Deformation of the Earth," Quaternary Research, Vol 2, pp 1-14.

Vertical movements of the earth's surface related to postglacial rebound, the eustatic rise in sea-level and the elastic deformation of the globe due to melting of late glacial ice sheets are calculated for simplified models of the earth. The movements of the ground are large and require a reevaluation of what is meant by eustatic sea-level change. This is defined here as an ocean-wide average change in mean sea-level and its measurement requires widely distributed observations weighted according to the areas of oceans they represent. Evidence of a postglacial (6000-0 years BP) relative rise in sea-level comes largely from regions affected by ground subsidence related to adjacent upward postglacial rebound movements in deglaciated areas: evidence

for a relative fall of sea-level comes from coastlines well removed from areas of rebound and which have been affected by a rise of the continental areas through compensation for the eustatic load. It is concluded: (1) no substantial eustatic change of sea-level in the past 6,000 years is required to explain postglacial sea-levels: (2) in the late glacial time the eustatic curve is probably more like the sea-level curve of Texas and Mexico than that of the Atlantic seaboard of the United States: (3) that the information of past sea-levels, when sufficiently widespread, can provide an important method of studying the deep mechanical structure of the earth. (Author).

356 WALDEN, A. T., and PRESCOTT, P. 1983. "Identification of Trends in Annual Maximum Sea-Levels Using Robust Locally Weighted Regression," Estuarine, Coastal, and Shelf Science, Vol 16, pp 17-26.

Estimates of the frequency of occurrence of extreme high sea-levels may be obtained from a sample of annual maxima. However, the presence of a secular trend may lead to serious doubts about the validity of analyzing these annual maxima as if they were a random sample from an extreme-value distribution. Robust locally weighted regression, employing a simple model, is used to illustrate how any secular trend may be estimated. The annual maxima may then be adjusted for this trend and more reliable estimates of the frequencies of occurrence of extreme sea-levels determined. (Authors).

357 WALTERS, R. A. 1982. "Low-Frequency Variations in Sea-Level and Currents in South San Francisco Bay," Journal of Physical Oceanography, Vol 12, pp 658-668.

In order to examine physical processes in the subtidal time range, sea-level and current m data for south San Francisco Bay (South Bay) were filtered using a low pass digital filter to remove tidal period variations, and then subjected to an empirical orthogonal function analysis. For the sea-level data, there is one dominant empirical mode that is correlated with nonlocal coastal forcing. A small amount of the variance is associated with local wind setup. For the current data, there are two dominant empirical models that correlate with local wind forcing and tidal forcing over the spring-neap cycle. In general, South Bay is dominated by coastal forcing on sea-level during all seasons, and dominated by wind and tidal forcing on the residual currents during the summer. (Author).

358 WANG, D.-P. 1979. "Low Frequency Sea-Level Variability on the Middle Atlantic Bight," Journal of Marine Research, Vol 37, No. 4, pp 683-697.

Low-frequency sea-level fluctuations on the Mid-Atlantic Bight, from Cape Cod to Cape Hatteras, and their relations to wind forcing were examined over a one-year (1975) period. The dominant sea-level fluctuations occurred at time scales of 4 days, and they were coherent over the entire Bight. On

the other hand, sea-levels were not coherent between the southern (south of Kiptopeake B.) and northern part at shorter time scales.

Local wind forcing was important from Cape Cod to Cape May; most of the sea-level change was driven by the alongshore (northeast-southwest) wind. In addition, the east-west wind set up a large surface slope between Nantucket and Sandy Hook. The wind set-up may be due to the bent coastline around Sandy Hook; the frictional effect may also play a role.

South of Cape May, the local alongshore wind forcing was dominant at time scales shorter than 3.3 days (in winter). At longer time scales, contribution from free shelf waves was significant. A southward phase propagation of 600 km/day was found between Cape May and Cape Hatteras, which is consistent with the shelf wave model. The dominance of free waves apparently was due to the lack of coherent wind forcing south of Cape May. (Authors).

359 **WATTS, A. B.** 1982. "Tectonic Subsidence, Flexure and Global Changes of Sea-Level," Nature, Vol 297, pp 469-474.

Tectonic models for the evolution of passive continental margins predict that following rifting, sediments should progressively onlap basement at the edge of a margin as the lithosphere cools and increases its flexural rigidity with age. The pattern of modelled onlap is strikingly similar to that used by Vail and colleagues to estimate sea-level rise through geological time. This similarity suggests that major portions of stratigraphical sequences at margins may have a tectonic, rather than eustatic, control. The patterns of onlap used by Vail and colleagues may be widespread, however, because several widely separated passive margins rifted at similar times, but they are unlikely to be worldwide. (Author).

360 **WEGGEL, J. R.** 1979. "A Method for Estimating Long-Term Erosion Rates From a Long-Term Rise in Water Level," US Army Engineer Coastal Engineering Research Center, Technical Aid. No. 79-2, pp 17.

A method is presented for estimating long-term erosion rates resulting from a rise in sea-level. The method is based on Bruun's (1982) method with an exponential curve fitted to the offshore beach profile. The exponential profile establishes the beach profile closure depth beyond which it is assumed waves do not move sand. An example problem using sea-level rise data of Hicks (1978) illustrates application of the technique. (Author).

361 WELLS, J. T. 1987. "Effects of Sea-Level Rise on Deltaic Sedimentation in South-Central Louisiana," Nummedal, D., Pilkey, O. H., and Howard, J. D., eds., Sea-Level Fluctuations and Coastal Evolution, Special Publication No. 41, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 157-166.

The birth of two new deltas in Atchafalaya Bay of south-central Louisiana has provided scientists with a unique opportunity to observe and measure processes of delta growth in their incipient stages. These regressive deposits, localized along a transgressive shoreline that is characterized by low-lying marsh and eroding barrier island, have developed in a setting in which compactional subsidence accounts for approximately 90% of the relative rise in sea-level. Unlike previous Holocene deltas of the Mississippi River and its distributaries, however, the deltas in Atchafalaya Bay may soon be growing under conditions of eustatic sea-level rise that is so rapid it will exceed rates of subsidence (1-2 cm/year).

Extrapolation of delta growth under three sea-level rise scenarios (subsidence only 1 cm/year, and 2 cm/year) indicates that as rates of eustatic sea-level rise approach or exceed rates of subsidence in south Louisiana, the subaerial deltas in Atchafalaya Bay will continue to grow but at slower rates. Even at the extreme rate of sea-level rise scenarios (subsidence only, 1 cm/year, and 2 cm/year) indicates that as rates of eustatic sea-level rise approach or exceed rates of subsidence in south Louisiana, the subaerial deltas in Atchafalaya Bay will continue to grow but at slower rates. Even at the extreme rate of sea-level rise of 2 cm/year, sediments will accumulate subaerially for another 80-100 years. Perhaps contrary to expectations, the slower a delta grows, because of rising sea-level, the more likely it is to be limited by inefficiency of channels and an inability to deliver sediments to its distal areas than it is to be limited by receiving basin area. Thus, a decrease in subaerial growth rate is reflected by a decrease in delta size.

In addition to producing smaller deltas, high rates of sea-level rise will affect sedimentation processes by leading to thicker sand bodies and deposition of sands farther upstream. High-energy environments of deposition, such as natural levees which grow primarily during spring floods, will keep pace with sea-level rise. Low-energy environments of deposition, such as back bar algal flats, will remain or become subaqueous as waters rise faster than sediments are introduced. Furthermore, high rates of sea-level rise will delay the extension of deltaic sediments to the continental shelf. This, in turn, will slow the growth of downdrift mudflats to the west. Accelerated growth of downdrift sediments will occur when Atchafalaya Bay becomes sediment-filled (2035-2085 a.d.), thus allowing a greater volume of sediments to enter the dynamic shelf region seaward of the bay. (Author).

362 WEYER, E. M. 1979. "Pole Movement and Sea-Levels," Nature, Vol 273, pp 18-21.

If the centrifugal force generated by a surface load caused the Pole to shift, sea-levels would fluctuate differentially around the world. Application of the 'hydrodynamic' formula to seemingly incongruous shoreline samples dated 14,700 to 28,000 BP suggests rhythmic polar oscillations on a 5,600 year cycle, synchronized with two glacial episodes. (Author).

363 WIGLEY, T. M. L., and JONES, P. D. 1985. "Influences of Precipitation Changes and Direct CO_2 Effects on Streamflow," Nature, Vol 314, pp 149-152.

Increasing atmospheric carbon dioxide concentrations are expected to cause major changes in the world's climate over the next 50-100 years. The impact of such changes on water resources, through changing precipitation and evaporation, will, however, be complicated by the direct effects of increasing CO_2 on vegetation. In controlled environment experiments, higher CO_2 levels cause the stomata of plants to close down, decreasing their rate of transpiration and increasing their water use efficiency. Reduced evaportranspiration would make more water available as runoff and could tend to offset the effects of any CO_2-induced reductions in precipitation or enhance the effect of precipitation increases. We consider here, in a simple but revealing analysis, the relative sensitivity of runoff to these two processes: changes in precipitation and changes in evaportranspiration. We show that, for low runoff ratios, small changes in precipitation may cause large changes in runoff. The magnitude and direction of these changes are, however, strongly dependent on the magnitude of the direct CO_2 effect on plant evaportranspiration. (Authors).

364 WILLIAM, P. W. 1982. "Speleothem Dates, Quaternary Terraces and Uplift Rates in New Zealand," Nature, Vol 298, pp 257-260.

Previous isotropic research on calcite stalagmites, stalactites and flowstones (speleothems) from New Zealand caves has focused on paleotemperature reconstruction. I report here the use of $^{230}Th/^{234}U$ and ^{14}C age data from speleothems to investigate the relationships between cave levels, emerged coastal terraces and uplift rates. In the north-west of the South Island of New Zealand, at least seven terraces, previously assigned to various stages in the Quaternary, are known to occur to at least 200 m above sea-level. The terraces sometimes cut across limestones which contain caves formed in association with past sea-levels. Uplift, followed by water table lowering and abandonment of cave passages by active streams, permitted speleothem deposition. Dating of these deposits given a minimum age for the cave level and hence also for any terrace to which it may be related, while successive dates at different levels yield an uplift rate for the area. Dates are presented from two localities, which suggest differential emergence rates of $0.27_{-0.40}^{+0.20}$, year^{-1} and $0.24_{-0.03}^{+0.06}$ mm year^{-1}. Thus re-evaluation is required on the uplift of these parts of the Southern Alps. (Author).

365 WILLIAMS, D. F. 1988. "Evidence For and Against Sea-Level Changes From the Stable Isotopic Record of the Cenozoic," Wilgus, C. K., Hastings, B. S., Kendall, C. G., Posamentier, W., Ross, C. A., and Van Wagoner, J. C., eds., Sea-Level Changes: An Integrated Approach, Special Publication No. 42, Society of Economic Paleontologists and Mineralogists, Tulsa, OK, pp 31-37.

The stable oxygen isotope record for the Cenozoic is characterized by a series of large third-order steps of +1 per mil superimposed on a long-term second-order trend. This second-order trend accounts for $\delta^{18}O$ change of

nearly +4 per mil from the early Eocene into the Neogene. The second- and third-order changes in the $\delta^{18}O$ signal are driven primarily by a combination of glacioeustatic sea-level and ocean paleotemperature changes. These changes are global responses to evolving circulation and climate patterns. Timing of the $\delta^{18}O$ events is in good agreement with the seismically defined changes in the coastal-onlap curve (Vail and others, 1977). Agreement in the timing of events supports a common mechanism, perhaps that glaciation is apparent throughout much of the record and certainly intensified beginning in the Neo gene. Agreement is not good between the magnitudes of apparent changes in sea-level using the EXXON onlap record and oceanic $\delta^{18}O$ events. Consideration of the $\delta^{18}O$, ice volume, and sea-level relationships during the Pleistocene suggests that sinusoidal eustatics, i.e., the rise and fall of sea-level being equal, is not a good assumption at fourth- and fifth-order sea-level events. Although interpretation of the $\delta^{18}O$ record is not without its assumptions and limitations, it offers an independent geochemical check on seismically defined changes in stratal patterns. (Author).

366 WINKER, C. D., and HOWARD, J.D. "Correlation of Tectonically Deformed Shorelines on the Southern Atlantic Coastal Plain," Geology, Vol 5, pp 123-127.

The assumption of absolute tectonic stability during Pleistocene time has influenced most previous attempts to map, name, and correlate relict shorelines and surficial deposits on the southern Atlantic coastal plain. This study is the first to correlate shorelines throughout the region independently of that assumption. Topographic shoreline features were mapped and differentiated into age groups on the bases of progradational discontinuities, contrasts in the state of preservation, and changes in coastal morphology. Three shoreline sequences are well preserved, permitting paleogeographic reconstructions. A combination of published and direct geomorphic evidence suggests that all three shoreline sequences have been deformed. Warping continued through Pleistocene time, following persistent Cenozoic structural features. (Authors).

367 WINOGRAD, I. J., SZABO, B. J., COPLEN, T. B., and RIGGS, A. C. 1988. "A 250,000-Year Climatic Record from Great Basin Vein Calcite: Implications for Milankovitch Theory," Science, Vol 243, pp 1275-1280.

A continuous record of δ variations in the continental hydrosphere during the middle-to-late Pleistocene has been obtained from a uranium-series dated calcitic vein in the southern Great Basin. the vein was deposited from ground water that moved through Devils Hole-- an open fault zone at Ash Meadows, Nevada--between 50 and 310 ka (thousand years ago). The configuration of the versus time curve closely resembles the marine and Antarctic ice core (Vostok) curves; however, the U-Th dates indicate that the last interglacial stage (marine oxygen isotope stage 5) began before 147 $\pm$ 3 ka, at least 17,000 years earlier than indicated by the marine record and 7,000 years earlier than indicated by the less well dated Antarctic record. This discrepancy and other differences in the timing of key climatic

events suggest that the indirectly dated marine chronology may need revision and that orbital forcing may not be the principal cause of the Pleistocene ice ages. (Modified Abstract).

368 **WORSLEY, T. R., and DAVIES, T. A.** 1979. "Sea-Level Fluctuations and Deep-Sea Sedimentation Rates," Science, Vol 203, No. 4379, pp 455-456.

Sediment accumulation rate curves from 95 drilled cores from the Pacific basin and sea-level curves derived from continental margin seismic stratigraphy show that high biogenous sediment accumulation rates correspond to low eustatic sea-levels producing lower land/sea ratios and hence slower chemical erosion of the continents, and vice versa. (Authors).

369 **WORSLEY, T. R., NANCE, D., and MOODY, J. B.** 1984. "Global Tectonics and Eustasy for the Past 2 Billion Years," Marine Geology, Vol 58, pp 373-400.

Continental freeboard and eustasy, as gaged by the relative position of the world shelf break with respect to sea-level, have varied by ±250 m from today's ice-free shelf break depth of about 200 m, during the past 600 Ma.

Assuming constant or uniformly accreting continental crust and ocean water volume on an ice-free world, sea-level fluctuations can be attributed to variation in the world ocean basin volume caused by changes in either its area or its depth relative to the world shelf break. An increase in volume and lowering of sea-level occur as: (1) the world ocean door ages, cools and subsides; (2) accreting continents collide, thicken and decrease in sea; and (3) poorly conductive continental platforms become thermally elevated due to a size-induced stasis over the mantle. Conversely, a decrease in the age of the world ocean floor, attenuation of continental crust during rifting, and an increase in continent number and mobility, will reduce the world ocean basin volume and raise sea-level.

Theoretical sea-level calculated from these principles correlates well with calibrated, first-order cycles of eustatic sea-level change for the Phanerozoic. The record closely fits a simple model of retardation and acceleration of terrestrial heat loss during alternating periods of supercontinent accretion and fragmentation. Calibrated to sea-level highstands, successive first-order marine transgressions and orogenic "Pangea" regressions characterize it self-sustaining, about 440 Ma plate tectonic cycle for the late Precambrian and Phanerozoic. The cycle can be recognized as far back as 2 Ga from the tectonic evidence of continental collision and rifting recorded in global orogenic peaks and mafic dike swarms, and may be related to major episodes of glaciation and evolutional biogenesis. (Authors).

370 **WYRTKI, K.** 1972. "Sea-Level During the 1972 El Niño," Journal of Physical Oceanography, Vol 7, pp 779-787.

Sea-level records at many island and coastal stations in the equatorial Pacific Ocean have been used to study its response and that of the associated

equatorial circulation to the 1972 El Niño. The response can be divided into five phases. Preceding El Niño, stronger than normal equatorial trade winds cause a buildup of sea-level in the western Pacific in 1970 and 1971. After the wind strength peaks, sea-level begins to drop slowly in the western Pacific. The first collapse of the wind field is followed by high sea-level along the eastern border of the ocean, actually initiating El Niño off Peru. The initial oceanic response seems to consist of an equatorial Kelvin wave, which has been successfully modeled by others, and a strong reduction of the South Equatorial Current. During the third phase sea-level drops very rapidly in the western Pacific, the equatorial trough is being filled, the South Equatorial Current retreats to the south of the equator, and the Countercurrent intensifies. Then follows a second peak of sea-level along the eastern side of the ocean including the coast of Central America and extremely low sea-level in the western Pacific. Thereafter, conditions return to normal, and sea-level changes are even more rapid than at the onset of El Niño. The development of a weaker event in 1975 is also analyzed, and it is shown that such an event terminates after the second phase. (Author).

371 WYRTKI, K. 1984. "The Slope of Sea-Level Along the Equator During the 1982/1983 El Niño," Journal of Geophysical Research, Vol 89, pp 419-24.

Observed deviations of monthly mean sea-level at seven island stations along the equator in the Pacific have been superimposed on the mean dynamic topography to determine the variations of the east-west slope of sea surface topography during the 1982/1983 El Niño. The normal east-west slope is eliminated in January 1983 when the bulk of warm water flowing eastward has reached the coast of South America. The sea surface remains essentially flat from January to June 1983, although zonal winds are very weak until April only. The slope requires several months to be reestablished, and in October and November, sea-level along the entire equator is 10 cm or more below normal, indicating a net loss of warm, water from the equatorial Pacific. (Author).

372 YATES, R. J., MILLER, D. E., HALKETT, D. J., MANHIRE, A. H., PARKINGTON, J. E., and VOGEL, J. C. 1986. "A Late Mid-Holocene High Sea-Level: A Preliminary Report on Geoarchaeology at Elands Bay, Western Cape Province, South Africa," South African Journal of Science, Vol 82, No. 3, pp 164-165.

Along the SW Cape coast, mean sea-level was around 2 m higher than at present, 3800 yr BP. Reactive emergence of the continental margins in response to loading of the ocean floor with Late Pleistocene meltwater has been invoked, taking into account rheological constraints.
(P.J. Jarvis)

373 YIJIAN, C., GUI, P., and WENGIANG. 1985. "Radiocarbon Dates from the East China Sea and Their Geological Implications," Quaternary Research, Vol 24, pp 197-203.

Radiocarbon analysis plays an important role in studying the Quaternary geologic history of the East China Sea. More than 200 ^{14}C dates have been published in various Chinese publications. The continental shelf of the East China Sea is one of the few large continental shelves in the world. Many low-lying flats and deltaic plains lie along the coast making it a favorable site for sea-level studies. Radiocarbon data from Neolithic sites, chenier ramparts, peaty deposits and submarine sediments converge to suggest that oscillations of sea-level have occurred; they also suggest that the lowest glacial sea-levels probably occurred between 22,000 and 19,000 yr B.P. Calculation of the volume of the Yangtze River Delta, together with ^{14}C dates, indicates that more than 89% of the solid particles carried by the river were deposited in the delta. Due to the sedimentary load, the crust beneath the delta has subsided isostatically and tilted seaward. Marine shells provide many acceptable ^{14}C dates, but because they are easily transported, most samples from the continental shelf cannot be directly related to the history of sea-level changes. (Authors).

374 YONEKURA, N., and OTA, Y. 1986. "Sea-Level Changes and Tectonics in the Late Quaternary," Recent Progress of Natural Sciences in Japan, Vol II, pp 17-35.

This paper summarizes recent studies on sea-level changes during the late Quaternary and the effects of plate tectonics on former shorelines. A chronology of Quaternary strata, geomorphic surfaces, a sea-level curve in South Kanto, and comparison of major sea-level changes is presented. The ages of coral reef terraces by Konishi et. al. (1974 and 1978) indicates 5 distinct sea-levels. These dates indicate that the coral reef terrace of Kikai Island formed at relatively high sea-levels have been uplifted at a high rate of about 1.5 to 2 m per thousand years.

Most of the Holocene sea-level curves in the mainlands of Japan including Hokkaido, Honshu, Shikoku, and Kyushu are characterized by a higher sea-level at 6,000 to 5,000 years BP, which is a culmination of the Post-glacial rapid rise in sea-level. Since then, the sea-level has been rather stable and has lowered to the present level with minor fluctuations.

It is suggested that the coastal region of Japan has been uplifted and deformed at accelerated rates during the late Quaternary. The nature and rate of the vertical crustal deformation deduced from former shoreline data were comparatively discussed among the coastal regions in and around the Pacific. (Authors).

375 YONEKURA, N., ISHII, T., SAITO, Y., MAEDA, Y., MATSUSHIMA, Y., MATSUMOTO, E., KAYANNE, H. , 1988. "Holocene Fringing Reefs and Sea-Level Change in Managaia Island, Southern Cook Islands," Palaeogeography, Palaeoclimatology, Palaeoecology, Vol 68, No. 2-4, pp 177-188.

Geological and geomorphological studies of the coast of Mangaia Island have revealed that there was a higher sea-level than the present in the mid-Holocene. The heights and ages of emerged microatolls on the emerged bench indicate that the sea reached a maximum level of +1.7 m around 4,000-3,400 yr BP, and then emergence is considered to have occurred between 3,400 and 2,900 year BP. At the same time, the reef crest formed in the period from 5,000 to 3,400 year BP emerged above the sea and suffered erosion. As a result of this change in sea-level, upward reef growth from the fore reef slope began to form a new reef crest by 2,000 year BP. The presence of fossil reef crests or eroded algal ridges on modern reef flats is a rather common feature in the South Pacific. The geomorphic development of such features can be explained by the effect of the late Holocene fall in sea-level. (Authors).

376 ZAHN, R., MARKUSSEN, B., and THIEDE, J. 1985. "Stable Isotope Data and Depositional Environments in the Late Quaternary Arctic Ocean," Nature, Vol 314, pp 433-435.

There has been much speculation about the history of the Arctic Ocean, particularly its response to the lake Quaternary climatic fluctuations. As a result, considerable data have been gathered from Arctic Ocean sediment cores to reconstruct glacial and interglacial Arctic Ocean paleoenvironments. But even with these data, the reconstructions and the correlations with the Quaternary chronostratigraphy have been unsatisfactory, mainly because of the lack of detailed stratigraphic data such as those provided by stable oxygen - isotope stratigraphy. Here we present stable isotope records from Arctic Ocean sediment cores which can be correlated convincingly with corresponding data from the North Atlantic. Together with lithostratigraphic data, they provide new evidence on Arctic Ocean history in relation to global late Quaternary climatic fluctuations. (Authors).

377 ZIMMERMAN, M. S. 1983. "Coastal Facets as Indicators of Shoreline Response to Rising Sea-Level," Unpublished Master's Thesis, Marine Environmental Sciences Program, State University of New York at Stony Brook.

Twenty-eight bathymetric and topographic profiles were constructed for a 35 km section of the south shore of Long Island, New York in order to examine adjustments of the shore to rising sea-level. The profiles were begun 30 m above mean sea-level, and extended offshore to a water depth of 35 m. The profiles were characterized by three facets; the glacial outwash surface, the beach/dune surface to a water depth of 12 m, and a ramp below 12 m. The outwash plain and ramp, and the beach/dune had slopes of 0.004 and 0.018 respectively. The ramp surface at a depth of 30 m was parallel to the outwash plain, but displaced vertically by 13.5 m. In response to a long-term rise of sea-level of 3 mm/year, erosion could occur without relative changes in either

the profile's geometry, or its position with respect to sea-level. Offshore deposition is not required. Long-term erosion of the 35 km section could supply much of the sand transported downdrift along the shore. (Author).

SUBJECT INDEX

8. Lake Levels

018, 024, 028, 040, 049, 067, 108, 130, 131, 132, 133, 134, 135, 158, 162, 220

9. Engineering Implications of Sea-Level Rise

001, 004, 017, 026, 034, 035, 036, 037, 054, 064, 078, 080, 081, 082, 083, 084, 096, 103, 104, 107, 109, 121, 126, 141, 143, 211, 241, 268, 298, 299, 312, 313, 360

10. Future Planning

016, 028, 149, 163, 187, 354

KEYWORD INDEX